ABSTRACT

AN INTERNSHIP ON DEVELOPING A SOLAR WATER PUMPING SYSTEM AT MICROSOL INTERNATIONAL™

by Karthik Prashanth Sivakumar

This report is a compilation of my six month internship experience on developing a solar water pumping system for Microsol International™ – a solar solutions providing company in United Arab Emirates (UAE). My responsibilities included planning and executing the project. A study on the water pumping activity in the UAE was done, based on which a product was designed for residential and light commercial applications. This phase was followed by developing and prototyping of the solar water pumping system. Based on the system design, financial models were constructed to understand cost of ownership and pay-back calculations for the consumer. The prototype was commissioned and tested at the local municipality followed by post installation monitoring and evaluation. Project proposal documents and technical installation manual were prepared for the product. After successful demonstration, the product was pitched to the government for promoting schemes targeting the residential sector.
AN INTERNSHIP ON DEVELOPING SOLAR WATER PUMPING SYSTEM AT
MICROSOL INTERNATIONAL™

An Internship Report
Submitted to the Faculty of Miami University
in partial fulfillment
of the requirements for the degree of
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Institute of Environmental Science
by
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2011

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ACKNOWLEDGEMENTS

I would like to thank Dr. Sandra-Woy Hazelton, Ms. Mary Ben Bonham, and Mr. Scott Johnston for the care they took in reviewing my report and the discussions that brought more clarity to this document. I am grateful to Microsol International (TM) for providing me with the internship opportunity and for making my stay pleasant. I would also like to acknowledge the contribution of Fujairah Municipality as a site donor while developing the water pumping system. I am highly indebted to my family and friends for being there for me in all my undertakings. Finally, I would like to thank all those who supported me in all respects throughout my internship.
1. Introduction

1.1 Scope of internship

This report is a compilation of my six month (Feb-Aug 2010) internship experience on developing a solar water pumping system for Microsol International™ – a solar solutions providing company based in United Arab Emirates (UAE). My responsibilities included planning and executing this project and establishing sales machinery for the solar water pumping system. This was done by studying water pumping activity in the UAE, based on which a product was decided for residential and light commercial applications. This phase was followed by design/development and prototyping of the solar water pumping system. Based on the system design, I constructed financial models to understand cost of ownership and pay-back calculations for the customer. The prototype was commissioned and tested at the local municipality followed by post installation monitoring and evaluation. Project proposal documents and a technical installation manual were prepared for this system. After successful demonstration, the product was pitched to the government for promoting schemes targeting the residential sector.

1.2 About the company

Microsol International™ is a solar solutions provider that has operated in the renewable energy/solar space for about 25 years. The company started out as solar system integrators but, over the years, has developed into component manufacturers as well. They have successfully integrated processes such as silicon wafer slicing, solar cell manufacturing and solar panel manufacturing into their operations (Microsol International 2011).
The system integration division at Microsol™ develops grid-tie, grid interactive and stand-alone (off-grid) systems. Grid-tie systems involve connecting the solar panels to the electricity grid where the excess energy generated is pumped into the grid through a meter. Grid interactive systems are grid-tie systems with battery backup. Such systems include residential rooftops, commercial rooftops and utility scale power plants. Stand alone systems are self-sufficient systems with (or without) battery backup, usually installed in areas where grid electricity is not available (Foster, Ghassemi and Cota 2010). The company’s product line includes solar-based stand alone street lighting systems, power packs for telecommunication towers and off-grid residential solutions. Though based in UAE, the company mostly caters to solar markets in Europe, Asia, Australia and Africa. Due to the recent shift towards renewable energy within UAE, the company decided to expand and establish its presence in their local market as well.

1.3 Sustainability and renewable energy scenario in UAE

UAE’s primary industries are oil production and tourism which are both highly polluting and energy intensive. It is currently experiencing an unprecedented increase in investment/development and multi-national corporate presence creating a global awareness on its environmental impacts (Shihab 2000). This has made the government realize the need for promoting green initiatives such as alternative energy and green building standards to mitigate
the environmental impact caused by their growth and operations (Emirate Green Building Council 2011). Since 2006, there has been tremendous growth in the alternative energy sector, particularly in the solar space as their geographic location provides them with ample sunshine. The recession of 2007 (The Great recession) played a major role in the adoption/enforcement of green building standards in UAE. The sovereign government of the UAE promotes the use of Solar Photovoltaic energy through incentives, grants, and strong private sector research and investment. This scenario has established solar energy as a viable and cost effective alternative source of power generation and is gaining attention on a global scale. The changing outlook of the Middle Eastern region from ‘World’s energy provider’ to ‘World’s clean energy provider’ has resulted in stringent standards for sustainable development by the Emirates Green Building Council (EGBC) and the renowned Masdar City project by the UAE government, the only project of its size aimed at creating scalable clean energy solutions (Masdar Project 2011).

UAE, being a desert region with negligible surface water, relies on desalinated water pumped across a vast network. A portion of this network functions on decentralized diesel pumping systems as it does not have access to grid electricity. The region also supports large irrigation activities such as commercial farmland and municipal irrigation (The Encyclopedia of Earth 2008). To capitalize on this situation and to add to the existing product line, an executive decision was made by Microsol International ™ to develop stand alone solar systems for pumping water.

The rest of the document is organized as follows: section 2 discusses background information related to solar technology and the industry; section 3 explains in detail the processes involved in product development/prototyping of the solar water pumping system and the internship deliverable documents. The report concludes with the internship timeline in sections 4.

2. Background

2.1 UAE region and location of company

The United Arab Emirates (UAE) is a country located in the southwestern part of the Asian continent. It consists of seven states (emirates) namely Abu Dhabi, Dubai, Fujairah, Ajman, Ras al-Khaimah, Sharjah, and Umm al-Qaiwain. City of Dubai and Abu Dhabi are well
known globally for their tourism and oil reserves respectively. In the recent years, UAE has attracted a lot of foreign investments through multinational companies. This led to development of special economic zones in the region to promote trade and investment. Microsol International (TM) is located in one such economic zone at Fujairah - the eastern coastal city of UAE. This supports the logistic operations of the company in European, African and Asian regions.

Figure 2 Location of Microsol International™ and its existing solar markets
2.2 Basic working principle of photovoltaic cells (PV cells)

Photovoltaics is the concept of generating electric power using solar cells to convert solar energy into electricity. The photons of light excite the electrons into a higher state of energy to create electricity. This is the fundamental working principle of Photovoltaic technology. PV cells are made from semiconductors like silicon. The basic assembly of a typical PV cell has an n-type and a p-type semiconductor between which is a junction. This setup is flanked by a front and a back contact. A glass cover is placed on top of the cell to provide protection from the environment. When more power is required, cells are electrically connected together to form photovoltaic modules, or solar panels. This process of converting light to electricity is called the “photovoltaic effect” (Foster, Ghassemi and Cota 2010).

![Figure 3 Cross-sectional view of a solar cell illustrating its working principle](image)

2.3 Solar PV Industry

The Solar PV industry comprises of two major technologies. These are Crystalline Silicon Solar Technology and Thin Film Solar Technology. The Crystalline Silicon Solar Technology currently has approximately 93% market share, compared to Thin Film technology of only 7% (Goetzberger, Luther and Willeke 2002).
Crystalline Silicon Solar Technology utilizes either Mono-Crystalline Silicon or Multi-Crystalline Silicon. The mono-Crystalline Silicon Technology uses high purity single crystal silicon wafers. The efficiencies of cells made using these wafers ranges from 16% to 19% whereas, the module efficiencies range from 14% to 16%. The Multi-Crystalline Silicon Technology uses high purity Multi crystal silicon wafers. The efficiencies of cells made using these wafers ranges from 14% to 16% whereas, the module efficiencies range from 12% to 14% (Goetzberger, Luther and Willeke 2002).

Figure 4 Chart indicating market share for crystalline and thin film solar PV technologies

Figure 5 Images of Mono-crystalline Wafer, cell and Module (Image Source: Microsol™)
The commercially viable types of thin-film technologies are Amorphous Silicon (a-Si), Cadmium Telluride (CdTe) and Copper Indium Deselenide (CIS). The amorphous silicon cells uses only about 1% of the total amount of silicon required to manufacture equivalent power mono-crystalline and poly-crystalline modules, having an efficiency ranging from 5-10%. Cells developed using cadmium telluride has efficiencies of approximately 10% but is yet to achieve commercial scale implementation. PV modules manufactured using Copper Indium Deselenide technology has demonstrated efficiencies of 12% (Goetzberger, Luther and Willeke 2002).
2.4 Basics of Solar water pumping

Using solar panels sunlight can be converted into electricity which can run pumps to transport water either from underground (submersible pumps) or on the surface (surface pumps). These solar pumps are driven by a permanent DC motor connected directly to an array of solar panels. Surface pumps are suitable for areas were the water level is within 5 m below pump level commonly from shallow surface water sources such as bore wells, open wells, reservoirs and lakes. These pumps have a total dynamic head of 14 m. The maximum suction head is typically 5m. Submersible pumps are completely immersed in water and function on the principle of water displacement. These pumps are suited both to deep well and to surface water sources. The initial and installation costs of these pumps are high but they have a longer life and greater reliability than surface pumps (Scherer 1993).
2.5 Advantages and limitations of solar pumps

Solar pumps are economically viable in remote locations without electric grid connectivity or fuel lines for diesel pumps as they could function as a stand-alone system. They have a very low operating cost and a well designed system requires very low maintenance. The limitations of a solar water pumping system are low and variable yield. A system that is appropriately sized to provide maximum efficiency would have low yield when compared to a similar size (power rating) conventional pump. The output of water varies with the intensity of sun on a seasonal and daily basis (National Renewable Energy Laboratory 1997).

3. Product development and Prototyping (solar water pumping system – LIFT™)

3.1 Solar water pumping project task sequence

On arriving for my internship, I was given a quick introduction to the staff and management at the company. I was given about two weeks to get myself familiarized with the company’s operations and its production facility (how solar cells, modules and systems were made). During this time frame, I developed a project task sequence for designing and developing a solar water pumping product. This was presented for changes and approval to the company’s top management during the project initiation meeting. The first phase of the project was to conduct background research and evaluate the market for pumping activity in UAE. Then, with the inputs of market evaluation, a photovoltaic water pumping system would be designed keeping in mind its intended customers (market sector). After a successful sales pitch, a prototype would be installed to demonstrate the functioning of the system. The required documentation deliverables for this project included a proposal document for the project and the design and installation manual for the solar water pumping product.
In order to accomplish the tasks of this project, I had to work with several departments within the company and interact with clients as well. I had closely worked with the sales team to understand the solar market and with the procurement team to research and obtain materials for prototype development of the product.
3.2 Evaluation of pumping market in UAE

3.2.1 Pumping applications in UAE

Pumping applications in UAE can be mainly divided into residential, commercial and industrial sectors. Municipal water pumping for homes and apartments is the major pumping activity within the residential sector. The other residential uses include landscape watering and water for swimming pools (Dubai Electricity and Water Authority 2009). Commercial pumping activity includes farm irrigation, landscape watering and recreational water pumping. Though UAE does not have arable lands for agricultural farms, there is a lot of commercial farming activity in the region. Being a major tourist destination, UAE has a lot of recreational water pumping such as fountains and pumping in water theme parks. Also, heavy water pumping is used for municipal landscape watering to maintain avenue trees and tropical landscapes in the desert climate (Solomon 2010). Petroleum industry, waste water treatment plants and desalination plants are the three major industries in UAE. A heavy scale of water pumping is done to support these industries.
3.2.2 Scale of water pumping activity

The majority of UAE is desert terrain and it does not have a surface water source except for a few desert oases. Desalinated sea water serves as the water source for the entire region. With the exponential growth of construction activity and increasing population, the water consumption pattern has seen a steep rise (The Encyclopedia of Earth 2008). Almost all of the water consumed in UAE is by major cities that lie along the coast. Dubai, a major city in UAE, has one of the highest per capita water consumption levels in the world. According to Dubai Electricity and Water Authority (DEWA), the total water consumption was about 83,600 million gallons for the year 2009. Of the total, 60% was consumed by the residential sector, 25% by the commercial sector, 4% by the industrial sector and 11% by others that include non commercial institutions such as police stations, mosques, Government schools and hospitals. About 95% of the water consumed came from desalination plants and the remaining 5% was from underground wells (Dubai Electricity and Water Authority 2009). This pattern of water consumption is almost identical in all the cities in UAE. Based on this water consumption pattern, the target market sectors were identified as residential and light commercial sectors.

![Water Consumption in (MIG*) for Dubai, UAE](image)

**Figure 10 Chart describing water consumption pattern by sector for the year 2009 in Dubai, UAE**

* Others* include non commercial institutions such as police stations, Mosques, Government schools and hospitals.

* Million Gallons
3.3 System Design

3.3.1 Feasibility of solar systems for pumping activity

The market study for water pumping activity in UAE revealed that the major water consuming sectors are residential and commercial. Following this, I performed a feasibility study to understand the limitations and boundaries of using solar photovoltaic systems to run the water pumps. For this study, possible scenarios of water pumping activities were constructed across all the market sectors (residential, industrial and commercial). A total of eight scenarios were constructed, three each for industrial and commercial sectors and two for residential sector. Pumping parameters such as water flow requirements, hours of operation, head/distance requirements were considered to understand the amount of power required to run these pumps and therefore the amount of solar energy. From this, the number of solar modules required for the pumping operation and the area it would occupy were calculated for each scenario. I created a comparison chart with all the scenarios and presented the findings to the top management at Microsol™. From the chart (Table 1), it was clear that the scenarios for pumping activity in the industrial and commercial sectors have very high pumping requirements in terms of the considered pumping parameters (water flow requirements, hours of operation, head/distance requirements). In addition, the number of solar modules required for the pumping activity is not economically and practically feasible. The chart also shows a possible scenario where solar powered pumps for pumping water in villas (residential sector) can be used.
Table 1: A comparison chart to understand feasibility of solar system for pumping activity by sectors

<table>
<thead>
<tr>
<th></th>
<th>INDUSTRIAL*</th>
<th>COMMERCIAL**</th>
<th>RESIDENTIAL***</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Oil &amp; Petroleum</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water flow req.</td>
<td>900 m³/hr</td>
<td>500 m³/hr</td>
<td>Best</td>
</tr>
<tr>
<td>Hours of operation</td>
<td>&gt;15 hrs /day</td>
<td>&gt;15 hrs /day</td>
<td>12-16 hrs/day</td>
</tr>
<tr>
<td>Head req.</td>
<td>150 m</td>
<td>60-1798 m</td>
<td>100 m</td>
</tr>
<tr>
<td>Power req.</td>
<td>5-40 KW</td>
<td>15-45 KW</td>
<td>7.4-15 KW</td>
</tr>
<tr>
<td>Material charasteristics</td>
<td>Low viscous chemical</td>
<td>High viscous fluids</td>
<td>Corrosion resistance</td>
</tr>
<tr>
<td>Number of Modules</td>
<td>460</td>
<td>172</td>
<td>16</td>
</tr>
</tbody>
</table>

*the pumping parameters (water flow requirements, hours of operation, head/distance requirements) and power requirements for pumping activity in the industrial sector were obtained from pump manufacturers (ARJ Group, Jameel Trading FZE) who supply to the oil & petroleum industries, sewage treatment and desalination plants in UAE

**the pumping parameters (water flow requirements, hours of operation, head/distance requirements) and power requirements for pumping activity in the commercial sector were obtained from Fujairah Municipality and inputs from commercial farm owners

***the pumping parameters (water flow requirements, hours of operation, head/distance requirements) and power requirements for pumping activity in the residential sector were obtained from local building contractors

# standard villas in UAE are either single storey or two storeys tall

## indicating varying depths at which underground water is available in UAE region (UAE Environmental and Agricultural Information Center)

~calculations based on pump and power requirements using Microsol’s proprietary software

~each module is a 140 Watt module of area 1.12 m²

Best - Maximum available flow rate

### 3.3.2 Solar Water Pumping System Design Options

On presenting the feasibility study, a decision was made by the top management to develop a solar water pumping product for the residential market. The next step was to look at various solar system design options. Solar panels convert solar energy into electricity which is in the form of direct current (DC) that can run DC water pumps directly. This would be the simplest and a highly efficient system design option. This means that the pump runs during sun hours as
long as there is enough solar energy to run the pump. Another option would be to store the energy generated by the solar panels onto a battery bank which could then run the pump. This means that the pump can run even during the night provided there is enough energy stored in the battery bank. This could possibly increase the number of solar modules in order to capture and store the required energy. Also, adding more components to the system (in this case a battery bank) reduces the overall efficiency of the system (Florida Solar Energy Center 2007).

Converting the stored energy from the battery bank into alternating current (AC) using an inverter can run pre-existing AC water pumps as well. Adding inverters and running AC water pumps further reduces the overall efficiency of the system. On considering these design options with the engineering team at Microsol™, we decided to use a DC water pump that pumps water during sunshine hours and substituted an overhead tank in place of a battery bank. Therefore, this system would pump water to the overhead tank during the day and would use the potential energy of water stored in the tank to deliver water during the night. Such systems are called PV Direct Surface water pumping systems (Meah, Fletcher and Ula 2008).

Figure 11 Various design options for solar water pumping system
3.3.3 System Design Concept and Prototype Development (LIFT™)

While working with the engineering team on prototype development, I designed a logo for the prototype system and named it “LIFT” (not an acronym). Later the name was adopted by the company as the standard product name. The prototype was designed for pumping water from a ground source to an overhead tank for varying heights up to 14 meters. The maximum flow rate is up to 170 liters per minute. The area required for the installation of the solar array is approx 6m². The system additionally employs electronics (optional) for occasional/seasonal heavy water pumping output. During daytime, PV array runs the pump and it can be switched off separately.

The system consists of:
1. Solar Modules
2. DC centrifugal surface pump
3. Fused disconnect switch with enclosure
4. Cable Kit for connecting the Solar Module to DC pump.
5. Electronics for pump overload protection.
6. Mounting Structure to hold the Solar Module at 23° tilt angle (for UAE) and can be fixed on roof, ground.
Figure 12 Schematic explaining the working of LIFT™ system (solar water pumping system)
The prototype was proposed to be installed at the local municipality for getting the government agencies on board and eventually promote the product through government schemes. Being a municipal office building, the water requirements were mostly during the day time and therefore did not require any battery backup for pumping during the night. In an emergency or during night time the pump can run on grid electricity.

### 3.4 Prototyping and Installation

#### 3.4.1 Installation of prototype

After procuring the components required for the prototype system, they were assembled at the factory and inspected for quality issues. The components were shipped to the installation
site (local municipality - Fujairah City, UAE). I was assigned a team of four technicians to carry out the installation process in a phased manner. First the installation site was prepped, then the pump was installed following which plumbing and electrical wiring were done and finally the PV array was installed.

3.4.1.1 Criteria for installation

The PV array must face south at a 23° angle and should be clear from shades throughout sunshine hours. The pump must be located close to the water source and close to the PV array (to minimize voltage losses).

3.4.1.2 PV array and pump installation process

Concrete foundations were used for footing the pump and the structures and were allowed to cure for 2 days. The legs of the module mounting structure were fixed to the concrete foundation blocks using anchor bolts. Then the structure was bolted on to the legs. Then the PV modules were fixed on to the structures and aligned for visual perfection. A distribution box enclosure was fixed on to one of the legs of the structure. The modules were wired using 2.5mm² wires and were connected to the junction box within the enclosure. A Fused disconnect switch was installed in the enclosure from which a 35mm² wire was connected to another enclosure near the pump. This enclosure contains the AC/DC converter, the float switch contactor coils and change over switch. The pump was positioned lower than the water source within its succession capacity (10ft) then bolted on to the concrete foundation. The suction and delivery pipes were sized accordingly to minimize the usage of pipe fitting joints to reduce friction loss.

3.4.1.3 Commissioning and Testing

Before switching on the system the voltage and current from the PV array was verified to see if they were as per design. Then voltage was checked across the system to see if there were any voltage losses. Then the system was checked for leaks in the pipelines and I measured the flow rate at the pump outlet.

3.4.2 Post Installation Monitoring and Evaluation

After commissioning, the system was constantly monitored and evaluated for a period of two weeks in order to verify its proper functioning. This gives an understanding of the actual performance of the system (subject to actual environmental conditions) that can be compared and validated with the performance of the design case. This was also done to get an insight on the
pattern of water consumption at the site. The following table shows the water level (in percentages) in the overhead tank at the municipality. The tank capacity is about 1000 gallons. The water levels and PV array output power characteristics were recorded three times a day, during high and low sun intensities. The solar pump starts to operate when the water level in the overhead tank is about 50% and stops when the tank is 90% full. From the table, it can be inferred that the water level at the end of each day is about three-fourths of the tank level on average, indicating that the system has been adequately sized for the water usage at the site.

Table 2 Water level indications and PV array output power characteristics during last week of July

<table>
<thead>
<tr>
<th></th>
<th>Morning (~8:30 am)</th>
<th>Afternoon (~1:00 am)</th>
<th>Evening (~4:30 pm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saturday</td>
<td>50%</td>
<td>90%</td>
<td>70%</td>
</tr>
<tr>
<td>Sunday</td>
<td>70%</td>
<td>90%</td>
<td>70%</td>
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<td>Friday</td>
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</tbody>
</table>

90 % is the upper cut off and 50 % is the lower cut off point for the water level using automated float switch

% water levels are visual estimates

PV array Output Power Characteristics – 5/Aug 12:55 pm

\[V_{oc} : 37.67 \text{ V}\]
\[I_{sc} : 17.25 \text{ A}\]

Load Voltage: 32.86 V

Load Current: 10.5 -11.3 A
Table 3 Water level indications and PV array output power characteristics during first week of August

<table>
<thead>
<tr>
<th>Day</th>
<th>Morning (~8:30 am)</th>
<th>Afternoon (~1:00 am)</th>
<th>Evening (~4:30 pm)</th>
</tr>
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<tbody>
<tr>
<td>Saturday</td>
<td>50%</td>
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</table>

**PV array Output Power Characteristics – 9/Aug 8:40 am**

- $V_{oc}$: 39.02 V
- $I_{sc}$: 8.65 A
- Load Voltage: 32.5 V
- Load Current: 7.3 A

**PV array Output Power Characteristics – 10/Aug 16:30 pm**

- $V_{oc}$: 38.77 V
- $I_{sc}$: 6.31 A
- Load Voltage: 21.07 V
- Load Current: 6.22 A

**PV array Output Power Characteristics – 10/Aug 17:05 pm (Pump stops functioning)**

- $V_{oc}$: 38.20 V
- $I_{sc}$: 3.78 A
- Load Voltage: 38.20 V
- Load Current: 0 A
3.5 Sales Pitch/Identifying the Customers

3.5.1 Promoting the Product

From a consumer perspective it is unnecessary and expensive to use solar based energy sources due to heavy subsidies on conventional electricity. Also the initial costs of solar based products are exponentially high, making the cost of ownership unrealizable. This being the case, it is highly unlikely to bring a transition from dependence on conventional energy to renewable energy. However, due to the increased demand for electricity, the government is being forced to set up more power plants involving higher investments. These circumstances have compelled the government to promote solar based schemes at a residential and light commercial scale (major electricity consuming sectors (Dubai Electricity and Water Authority 2009)) where the initial costs of setting up stand-alone solar systems can be taken care of by the government. Such schemes would create public awareness and increase use of solar energy thereby reducing the peak demand for electricity.

On considering all the above mentioned factors, promoting solar based products through government schemes focusing on residential sector as a target market, seems to be an assuring strategy for promoting the solar pumping product line for Microsol International™. As per the strategy, an effort to develop such schemes with the local municipality was initiated, where once the government officials were convinced by the functioning of the solar water pumping system, they would install the product at all the municipal offices.

3.6 Deliverable Project Documents

As part of the internship, I created a technical design and installation manual for the prototype for the solar water pumping system - LIFT™. The objective of the design manual was to present data and information on the design of a Water Pumping Solution in a readily usable form. It is a compilation of the concepts/system design scheme which forms the basis for the design/installation of LIFT Water Pumping systems. Along with photographic documentations, charts, tables and design procedures are summarized in the Design Manual. I also compiled and designed an information packet that is intended for future interns at Microsol™. The information packet is designed to answer as many questions as possible about the company, its organizational structure and its operations. This document clearly states the roles and
responsibilities of an intern, timeline and deliverables and reporting structures. This effort was much appreciated and was adopted as an internal document for the company.

Figure 14 Deliverable project documents
4. Project Timeline

Figure 15 Figure indicating the proposed and actual project timeline
5. Appendix

5.1 APPENDIX I - Glossary of terms

**Ac-alternating current** - The standard form of electrical current supplied by the utility grid and by most fuel powered generators in which the polarity and the direction of current alternates.

**Amps (ampere)** - the unit of measuring electrical current (compared to the flow rate of water in pipes).

**Array** - several solar panels arranged together, either in series and/or parallel.

**Borehole** - drilled well

**Centrifugal pump** – A pumping mechanism that spins water using an “impeller” in which water is pushed out by centrifugal force.

**Current** - The rate at which electricity flows through a circuit, to transfer energy (measured in amperes, commonly called amps)

**Dc direct current** - The type of power produced by photovoltaic panels and by storage batteries. The current flows in one direction and polarity is fixed.

**Dc motor, brush type dc** - The traditional dc motor, in which small carbon blocks, called "brushes" conduct current into the spinning portion of the motor. They are used in dc surface pumps and also in some dc submersible pumps.

**Energy** - the product of power and time, measured in watt-hours.

**Grid power** - Electrical power supplied by the utility company.

**Open circuit voltage** - voltage of a solar panel (PV module) with nothing connected.

**Photovoltaic** - the phenomenon of converting light to electric power.

**PV** - the common abbreviation for photovoltaic

**PV array direct system**- the use of electric power directly from a photovoltaic array, without storage batteries to store or stabilize it. Most solar water pumping systems work this way, utilizing a tank to store water.

**PV module** - An assembly of PV cells framed into a weatherproof unit (commonly called a "PV panel")

**Sand-alone solar system** - refers to a solar system that functions independently using a solar array (and batteries in some cases) without relying on grid electricity or other sources.
**Submersible pump** - A motor/pump combination designed to be placed entirely below the water surface.

**Surface pump** - A pump must be placed within 10-20 feet above the surface of the water.

**Voltage** - The measurement of electrical potential. (Analogy: pressure in a water pipe).

**Voltage drop** - loss of voltage (electrical pressure) caused by the resistance in wire and electrical devices. Proper wire sizing will minimize voltage drop, particularly over long distances. Voltage drop is determined by four factors: wire size, current (amps), voltage, and length of wire.

**Voltage nominal** - Nomenclature for expressing standard range of voltage.

**Voltage open circuit** - The voltage of a PV module or array with no load

**Voltage peak power point** - The voltage at which a photovoltaic module or array transfers the greatest amount of power (watts).
5.2 APPENDIX II – Prototype installation pictures

Figure 16 PV array installed for the solar water pumping system at Fujairah Municipality (UAE)
Figure 17 DC Solar centrifugal pump installed at Fujairah Municipality (UAE)
Figure 18 Prototype of solar water pumping system (LIFT™) developed by Micorsol installed at Fujairah Municipality (UAE)
References


