LIST OF CONTENTS

| Chapter | | Page |
|---------|-------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|
| 1 | INTRODUCTION | 1 1 1 2 2 |
| | Scope of the study | . 4 |
| 2 | LITERATURE REVIEW The PV Water Pumping system at Nong | 3 |
| | Sanuan village The PV Water Pumping System at King Mongkut's University of Technology Thonburi The PV Water Pumping system at Lahansai, Burirum | 3 7 |
| | Province | 8 |
| 3 | PHOTOVOLTAIC WATER PUMPING TECHNOLOGY Fundamental of solar cell Characteristic of solar cells Photovoltaic Pumping system | 16 17 22 |
| | | 29 |
| 4 | SYSTEM DESIGN & METHODOLOGY. Data base of this system. System design. Instrumentation. Collection of data. | 35 35 36 37 38 |
| 5 | DATA ANALYSIS | 42 52 63 |
| 6 | ECONOMIC ASSESSMENT Procedure for economic assessment of the PV water pumping system | 65 65 |
| 7 | CONCLUSION & RECOMMENDATION. Conclusion. Recommendation. | 74 74 74 |
| REF | TERENCES | 76 |

| Chapter | | Page |
|---------|---------------------------------------------------------------------------------------------------|-----------|
| | APPENDIXA. Software Installation and set upB. Results and calculation from testing of solar water | 78 |
| • | pumping system | 84 106 |
| | LIST OF NOMENCLATURE | 118 |
| | BIOGR A PHY | 119 |



LIST OF TABLES

| Table | | Page |
|-------|--------------------------------------------------------------------------|------|
| 1 | Specifications of the System | 9 |
| 2 | Compares the design system and four configurations of the | . 1 |
| | actual installation | 10 |
| 3 | The highest electric power from PV | 50 |
| 4 | Fill Factor (when $G_T = 700 \text{ W/m}^2$) | 50 |
| 5 | PV efficiency of the module | 51 |
| 6 | The cost of solar water pumping system | 68 |
| 7 | Life Cycle Cost (LCC) Calculation | 69 |
| 8 | Unit water cost calculation | 70 |
| 9 | The cost of diesel water pumping system | 71 |
| 10 | Life cycle cost (LCC) calculation | 72 |
| 11 | Unit water cost calculation | 73 |
| 12 | Results and calculation from testing of solar water pumping | |
| | system at 20/3/2000 | 84 |
| 13 | Results and calculation from testing of solar water pumping | |
| | system at 21/3/2000 | 87 |
| 14 | Results and calculation from testing of solar water pumping | |
| | system at 22/3/2000 | 90 |
| 15 | Results and calculation from testing of solar water pumping | |
| | system at 23/3/2000 | 93 |
| 16 | Results and calculation from testing of solar water pumping | 111 |
| | system at 24/3/2000 | 96 |
| 17 | Results and calculation from testing of solar water pumping | |
| | system at 25/3/2000 | 99 |
| 18 | Results and calculation from testing of solar water pumping | |
| | system at 26/3/2000 | 102 |
| 19 | Results and calculation for testing of PV module (Part 1: | |
| | Temperature constant, Radiation variable) | 106 |
| 20 | Results and calculation for testing of PV module (Part 2: | |
| _ 5 | Radiation constant, Temperature variable) | 109 |
| 21 | Relation between the radiation and I _{SC} and V _{OC} | 115 |
| 22 | Relation between the temperature and I _{SC} and V _{OC} | 116 |

LIST OF FIGURES

| Figure | • | Page |
|--------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| 1 | The monitoring in the PV pumping station will provide environmental data (irradiation and temperature), electrical data (DC voltage and current, AC power and frequency) as well as hydraulic data (pressure, flow rate) | 5 |
| 2 | An important tool to understand and to interpreted the measured data is the energy flow analysis. The analysis is based on a detailed computer model of the investigated system and the simulation, using measured environmental data, pa breakdown of the individual energy losses in the | |
| 3 | system | 6 |
| 4 | NO.4: Aug93-May94) | 12 · 13 |
| - | incident solar irradiation for four configurations Current – voltage characteristic of an ideal voltage source | 16 |
| 5 6 | Current – Voltage Characteristic of an ideal current Current – Voltage Characteristic curve of an ideal current | |
| U | CONTROL | 16 |
| 7 | Idealized characteristic curves of an electric are welder | 17 |
| 8 | Characteristic curve of current – voltage of a solar panel at | 1.0 |
| | 25 °C and varying solar radiation | 18 |
| 9 | Characteristic curve of current – voltage compare with 0 – 100 | 19 |
| 1.0 | and 25°C of temperature at 1000 W/m^2 | N /// |
| 10 | Open circuit voltage and short circuit current as a function of | 20 |
| 11 | the radiation intensity | 20 |
| 12 | More sophisticated equivalent circuit diagram for a solar cell | 22 |
| 13 | Main components of a PV pumping system | 23 |
| 14 | Construction of d.c. motors | 25 |
| 15 | Principle of a centrifugal pump (Water is thrown out from the center of the pump because of the centrifugal force created as the impeller rotates | 27 |
| 16 | Schematic of a positive displacement pump. When the piston moves down, the foot valve closes and water passes to the chamber above the piston. On the upward stroke the upper valve closes, the foot valve opens and water is lifted to fill the chamber below the piston. | 28 |
| 17 | Phovoltaic arrays at Energy Park, Naresuan University | 32 |
| 18 | Grundfos motor-pump selection diagram | 39 |
| 19 | Grundfos for SP 5A-7 as used in the measurements | 40 |
| 20 | Diagram of the system | 41 |
| 21 | PV connection circuit | 42 |

| Figure | | Page |
|--------|----------------------------------------------------------------------------|------|
| 22 | Relationship between voltage and current | 44 |
| 23 | Relationship between voltage and power | 45 |
| 24 | Relationship between voltage and current | 46 |
| 25 | Relationship between voltage and power | 46 |
| 26 | The relation between the radiation and I _{sc} and V _{oc} | 49 |
| 27 | The relation between the temperature and I_{sc} and V_{oc} | 49 |
| 28 | Diagram of the PV pumping system | 52 |
| 29 | Relationship between solar, power and volume | 53 |
| 30 | Relationship between daytime and efficiency of system | 53 |
| 31 | Relationship between daytime and solar radiation | 54 |
| 32 | Relationship between daytime and PV temperature | 54 |
| 33 | Relationship between daytime and PV current | 55 |
| 34 | Relationship between daytime and PV voltage | 55 |
| 35 | Relationship between daytime and volume | 56 |
| 36 | Relationship between daytime and PV efficiency | 56 |
| 37 | Relationship between daytime and motor/pump efficiency | 57 |
| 38 | Relationship between daytime and PV water pumping system | |
| | efficiency | 57 |
| 39 | Relationship between power out put and volume of water | 59 |
| 40 | Relationship between solar radiation and efficiency of system | 59 |
| 41 | Relationship between solar radiation and current output | 60 |
| 42 | Relationship between solar radiation and voltage output | 60 |
| 43 | Relationship between solar radiation and PV efficiency | 61 |
| 44 | Relationship between solar radiation and motor/pump | |
| | efficiency | 61 |
| 45 | Relationship between solar radiation and PV water pumping | |
| | system efficiency | 62 |
| 46 | Relationship between solar radiation and volume | 62 |
| 47 | The linear regression equation of PV water pumping system | |
| | (20 March 2000) | 63 |
| 48 | The linear regression equation of PV water pumping system | |
| | (20-27 March 2000) | 64 |
| 49 | Step by step Procedure for economic assessment of water | |
| | numning system | 65 |