A Major Project

Report on

Solar Desalination Plant with PLC Based Monitoring and Control

Submitted in partial fulfilment of the requirements for the

Award of the Degree of

BACHELOR OF TECHNOLOGY

IN

ELECTRONICS & INSTRUMENTATION ENGINEERING

By

KOVURI TRIVENI	**(218W1A1024)**
KOLLEBOINA ANUSHA	**(218W1A1022)**
GHANTA JAYA KEERTHANA	**(218W1A1014)**
SHAIK SHARMILA	**(218W1A1046)**

Under the guidance of

Mrs. K. Mrudula M.Tech

ASSISTANT PROFESSOR

DEPARTMENT OF ELECTRONICS AND INSTRUMENTATION ENGINEERING

VELAGAPUDI RAMAKRISHNA
SIDDHARTHA ENGINEERING COLLEGE

(Affiliated to JNTUK, Kakinada)

Sponsored by SAGTE, Kanuru, Vijayawada-520 007

(Approved by AICTE, Accredited by NBA and NAAC A+ GRADE)

2024-2025

DEPARTMENT OF ELECTRONICS AND INSTRUMENTATION ENGINEERING

V.R. SIDDHARTHAENGINEERING COLLEGE

(AUTONOMOUS)

CERTIFICATE

This is to certify that the major project titled **"Solar Desalination Process with PLC Based Monitoring and Control"** is a bonafide record of work done by **K. TRIVENI (218W1A1024), K. ANUSHA (218W1A1022), G. JAYA KEERTHANA (218W1A1014), SK. SHARMILA (218W1A1046)** under my guidance and supervision and is submitted in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Electronics and Instrumentation Engineering, V.R.Siddhartha Engineering college, (Autonomous, Affiliated to JNTUK) during the academic year 2024-2025.

(Mrs. K. MRUDULA)
M. Tech .,
Assistant professor,
Dept. of EIE.

(Dr. G. N. SWAMY)
M. Tech., Ph.D.,
Professor & Head,
Dept. of EIE.

ACKNOWLEDGEMENTS

We would like to express our heartfelt gratitude to our guide **Mrs. K. Mrudula, Assistant Professor, Department of Electronics and Instrumentation Engineering**, **VR Siddhartha Engineering College.** She has given us tremendous support in both technical and moral front. Without her support and encouragement, we would never have been able to complete the Major Project successfully.

We are profoundly grateful to **Dr. G. N. Swamy, Professor, Head of the Department, Electronics and Instrumentation Engineering, VR Siddhartha Engineering College,** for his kind and whole hearted support and valuable guidance throughout the Major Project.

We are also grateful to **Project Review Committee members, Dr. N. Swathi, Assistant Professor, EIE and Dr. P Srinivas, Associate Professor and Program Coordinator, EIE** for their supervision and valuable suggestions and other teaching and non-teaching staff for their kind co-operation.

We are thankful to **Dr. A.V. Ratna Prasad, Principal, VR Siddhartha Engineering College,** for his support during the completion of the Major Project.

We would also like to express our special gratitude and thanks to family and friends for their continuous support.

K. TRIVENI

K. ANUSHA

G. JAYA KEERTHANA

SK. SHARMILA

CONTENTS

LIST OF FIGURES

ORGANIZATION OF THE MAJOR PROJECT

CHAPTER 1

This chapter deals with the introduction of the project.

CHAPTER 2

This chapter deals with the literature survey.

CHAPTER 3

This chapter explains the methodology and design flow of the proposed system.

CHAPTER 4

This chapter is about WPL Soft V2.52 Software which we have used to execute the project.

CHAPTER 5

This chapter gives the software execution procedure.

CHAPTER 6

This chapter is about the results and discussion of the proposed system.

ABSTRACT

The growing demand for fresh water, combined with the depletion of natural freshwater sources, has necessitated the development of sustainable and efficient desalination technologies. This project presents a Solar Desalination System integrated with a Programmable Logic Controller (PLC) for real-time monitoring and control, aiming to provide an eco-friendly, automated solution for converting saline water into potable water.

The core of the system is a solar still, which utilizes solar thermal energy to evaporate seawater or brackish water. As the sun heats the water, the vapor rises, leaving behind salts and impurities. The vapor then condenses on a cool surface, and the resulting distilled water is collected. This natural and energy-efficient process is enhanced by integrating it with a PLC-based control system.

The use of solar energy ensures low operational costs and a sustainable footprint, while the automation via PLC enhances reliability, scalability, and ease of use. This combination provides a robust and modern approach to desalination, suitable for deployment in remote coastal or arid areas where both electricity and fresh water are scarce. this project demonstrates the practical application of renewable energy and industrial automation in addressing global water scarcity issues, making it a significant step toward sustainable water management.

CHAPTER 1
INTRODUCTION

A significant portion of the global population lacks reliable access to safe drinking water, leading to severe health issues and high mortality rates. Traditional water purification methods often rely on electrical energy, which may not be available in remote or underdeveloped regions. Solar energy presents a sustainable and accessible alternative for powering water purification systems. This project focuses on developing a solar-powered water purification system that employs thermal desalination through a solar heater, complemented by a series of filtration stages, to provide clean drinking water in off-grid areas.

Various methods have been explored for water purification, particularly in off-grid settings:

1. **Solar Water Disinfection (SODIS):** Utilizes solar radiation to inactivate pathogens in water. While effective for microbial disinfection, it does not remove dissolved salts or chemical contaminants.
2. **Solar Water Distillation:** Involves evaporating water using solar heat and condensing the vapor to obtain purified water. This method effectively removes salts and contaminants but typically has low output and requires large setups.
3. **Reverse Osmosis (RO):** Employs semi-permeable membranes to remove a wide range of contaminants, including salts. RO systems are effective but require pre-treatment to prevent membrane fouling and are energy-intensive.

Integrating thermal desalination using a solar heater with a comprehensive filtration system can address the limitations of these individual methods, providing a holistic solution for water purification in energy-constrained environments.

1.1 MOTIVATION

The motivation behind this project stems from the urgent global need for sustainable and efficient methods to produce clean drinking water. With water scarcity affecting millions of people worldwide particularly in arid, coastal, and remote regions there is a critical demand for alternative water sources. Desalination of seawater offers a viable solution, but traditional desalination methods are often energy intensive, expensive, and heavily reliant on fossil fuels, making them unsuitable for decentralized or off-grid areas. Solar desalination, on the other hand, presents an ecofriendly and renewable approach by utilizing the sun’s thermal energy to evaporate and purify water. However, conventional solar stills suffer from low efficiency and lack of operational control. This project aims to overcome these limitations by integrating a PLC-based monitoring and control system that automates key aspects of the desalination process such as temperature regulation, water flow control, and real-time system monitoring. The PLC ensures that the system adapts to changing environmental conditions, maintains optimal performance, and operates with minimal human intervention. By combining the sustainability of solar energy with the intelligence of industrial automation, this project aspires to deliver a low-cost, efficient, and scalable solution that addresses both environmental and humanitarian challenges, particularly in regions lacking access to reliable water and power infrastructure.

1.2 PROBLEM DESCRIPTION

In many rural and underdeveloped regions, communities face challenges related to:

- Limited or no access to potable water.
- Dependence on saline or contaminated water sources.
- Lack of reliable electricity to power conventional water purification systems.
- Health risks associated with waterborne diseases due to inadequate water treatment.

Addressing these challenges requires a sustainable, cost-effective, and energy independent solution to purify water from various sources.

CHAPTER 2
LITERATURE SURVEY

A.A. EI-Sebaii et al. (2009) proposed a method for Solar water Distillation [1]. This study provided a comprehensive review of solar water distillation methods, particularly focusing on solar stills. It highlighted how thermal energy from the sun can be effectively used for desalination without any external power supply. Key Findings: Solar distillation is effective for saline water purification but limited by low daily output.

B.S. Richards et al. (2008) proposed a method for Field trails of hybrid solar photovoltaic and thermal water purification system [2]. Richards and team developed hybrid systems that combine solar photovoltaic (PV) and thermal system to both power and purification unit. Key Findings: Thermal desalination and filtration integration can increase water yield and improve quality.

S. Kalogirou (2005) proposed a method for Sea water desalination using renewable energy sources [3]. Kalogirou focused on the role of renewable energy in desalination, especially using solar energy for heating and powering reverse osmosis. Key Findings: Thermal desalination works best when coupled with proper pretreatment filters.

Ghaffour, Missimer, and Amy (2013), in their influential review titled “Renewable Energy-Driven Desalination Technologies [4]: A Comprehensive Review” published in the Renewable and Sustainable Energy Reviews, examine the technical, economic, and environmental aspects of integrating renewable energy sources with desalination systems. The authors explore various renewable options such as solar, wind, geothermal, and wave energy, and assess their suitability in powering desalination technologies including reverse osmosis (RO), multi-stage flash (MSF), and membrane distillation (MD). The review provides comparative data on energy consumption, system efficiency, and cost-effectiveness, revealing that solar energy both photovoltaic and thermal is the most promising source due to its wide availability in water-scarce regions. The authors also address the potential for hybrid renewable systems and emphasize the importance of selecting the right desalination-re energy pairing based on geographic and climatic conditions. Their findings underscore the critical role that renewable energy can play in sustainable water production, directly supporting the design and implementation of solar-powered desalination systems, particularly when combined with intelligent control technologies like PLCs for optimized performance.

El-Naas, Al-Marzouqi, and Makhlouf (2011), in their research article titled "A Solar-Powered Membrane Distillation System for Brine Treatment" [5] published in the journal Desalination, present the development and testing of a pilot-scale solardriven membrane distillation (MD) system aimed at treating high-salinity brine. The study focuses on harnessing solar thermal energy to heat the feedwater, which then passes through a hydrophobic membrane where only vapor permeates and condenses into fresh water, leaving salts and contaminants behind. The researchers designed the system to operate in arid regions where conventional energy sources are scarce but solar radiation is abundant. Their experimental results show that the MD system, when powered entirely by solar energy, can achieve a steady and efficient distillation process with minimal operational complexity. Furthermore, the paper discusses system efficiency under varying solar radiation conditions and highlights the modularity and scalability of the setup for remote deployments. This work is highly relevant to solar desalination projects as it demonstrates a feasible integration of solar energy with membrane-based desalination and opens the door for automation and remote monitoring using PLCs to maintain consistent output quality and optimize energy use.

Tiwari, G.N. et al. (2003) proposed a method for Design and performance of an improved solar still [6]. This paper explores the efficiency enhancement of solar stills and their effectiveness in removing salts and pathogens. Key Findings: Using solar energy with insulation and heat traps improves evaporation rate.

Al-Karaghouli and Kazmerski (2013), in their paper titled "Energy Consumption and Water Production Cost of Conventional and Renewable-Energy-Powered Desalination Processes" [6] published in the Renewable and Sustainable Energy Reviews, conduct a detailed comparison of energy requirements and cost implications of various desalination techniques powered by both traditional and renewable energy sources. The study evaluates the performance of methods like reverse osmosis (RO), multi-stage flash (MSF), and multi-effect distillation (MED), highlighting how the integration of solar energy, especially photovoltaic and thermal systems, can significantly reduce the operational costs over the system's lifetime. The authors provide case studies and cost models that demonstrate how solar-powered desalination becomes more viable and competitive in remote or off-grid regions. Their work underscores the long-term economic benefits and sustainability of using solar energy, despite its higher initial investment, and provides a strong argument for pairing such systems with automated control strategies like PLCs to ensure efficient energy and process management.

Gude, Nirmalakhandan, and Deng (2010), in their article “Renewable and Sustainable Approaches for Desalination” [7] also published in Renewable and Sustainable Energy Reviews, explore the integration of multiple renewable energy sources such as solar, wind, and geothermal into desalination systems. Their study presents a detailed analysis of hybrid energy systems, noting that the variability and intermittency of solar radiation can be effectively balanced by combining it with other renewable sources, thus improving reliability and system efficiency. The authors argue that multi-source energy integration not only enhances the sustainability of desalination but also enables continuous operation even under fluctuating environmental conditions. This approach aligns well with modern control solutions like PLCs, which can manage complex inputs and outputs in real-time, allowing seamless transitions between energy sources and ensuring optimal performance of the desalination process

Chaudhari, M. et al. (2017) proposes Solar-powered water purification system with multi-stage filters [8]. The authors proposed a solar water purifier that integrates sediment, carbon, RO membrane, and UV filters. Key Findings: Multi-stage filtration ensures improved water quality by removing physical, chemical, and microbial contaminants.

Shatat and Riffat (2012), in their study published in the International Journal of Low-Carbon Technologies [8], discussed different ways to turn salty water into clean water using both regular and renewable energy sources. They explained how systems like reverse osmosis and solar distillation work and focused on how solar energy can be used in areas that have a lot of sunlight. They also pointed out that picking the right system depends on things like the local weather and available resources. This makes it clear how useful solar energy can be, especially when combined with automatic systems like PLCs to help control the process smoothly.

Rajesh and Suresh (2016) showed how a PLC can be used to control water levels automatically [9]. Their system used sensors to check the water level and turned pumps on or off based on that. This system worked well without any need for people to control it manually. This is very useful in desalination systems too, because keeping the water at the right level is important for everything to work properly. Their work shows that PLCs are simple, reliable, and a great choice for water management.

Al-Ali and his team (2011) created a smart system that manages energy at home using solar power [10]. Their system switched between different power sources and made sure energy was used in the best way. Even though it was made for homes, the same idea can be used in solar desalination plants to manage solar energy and keep everything running smoothly. They showed how PLCs can help manage energy use and automate decisions to save power.

Zurita-Milla et al. (2005) worked on a system that lets people monitor and control desalination plants from far away using PLCs and a computer interface called SCADA [11]. Their system could spot problems early and allowed operators to fix things remotely. This is really helpful for solar desalination plants that are in far-off places where it's hard to send people all the time. The setup made the system more reliable and easier to run with less effort.

Tiwari and Singh (2004) developed a solar still that could make clean water and electricity at the same time [12]. They used both solar panels and solar heat in their design. The electricity produced was enough to power small devices like sensors or controllers. This makes it perfect for remote desalination plants because it doesn't need extra power. Their system is efficient and helps the plant run without outside help, especially when using automation like PLCs to control the flow of water and energy.

Kabeel and Abdelgaied (2016), in their study "Performance Enhancement of Solar Still Using a Rotating Drum and Wick" published in Desalination [13], worked on improving solar stills, which are basic devices used to make fresh water from saltwater using the sun's heat. They added a rotating drum and a wick to make the system work better and produce more fresh water. This idea is important for solar desalination plants, as it shows how simple devices can be improved for better performance. The system could also be managed more easily with PLCs to control the rotating drum and wick, making it run more efficiently without much manual work. Luque and Hegedus (2011), in their Handbook of Photovoltaic Science and Engineering [14], explain how solar panels (photovoltaic systems) work and how they can be used in many applications, including desalination. Their book gives a deep dive into how solar panels are designed, how they perform, and how they can be used to power desalination systems. This is very useful for anyone designing solar desalination plants, as it helps ensure the right amount of solar energy is used efficiently for the desalination process.

Abd Elbar et al. (2019) did an experiment on a new type of solar desalination system powered by solar panels in their study “Experimental Investigation of a New Solar Desalination System Integrated with Photovoltaic Panels” [15]. They showed how solar panels could directly power desalination systems. The study gives valuable information on how to combine solar energy with desalination and improve the efficiency of the process. It also highlights the importance of using automation like PLCs to control the system and make it run smoothly.

Solar Desalination Techniques [16] Various studies have explored the use of solar stills for desalination. Basic single-slope and double-slope solar stills are low-cost solutions but suffer from low water output. Research by Tiwari and Singh (2016) examined modifications such as using glass covers, reflectors, and phase change materials to improve thermal performance and increase evaporation rates. However, these improvements still lack dynamic control and responsiveness to environmental changes.

Use of Automation in Desalination [17] Research by Kumar et al. (2018) explored the use of PLC and SCADA systems in water treatment plants to monitor flow rates, water quality, and system status. Their findings highlighted the importance of real-time monitoring and fault detection in ensuring system reliability and reducing maintenance time. However, the integration of PLC with solar-based desalination systems remains limited and is still a developing area.

Hybrid and Active Solar Desalination Approaches [18] To improve productivity, researchers have moved toward active solar desalination systems that integrate solar thermal collectors and photovoltaic (PV) panels. A study by El-Agouz and Abugderah (2014) showed that using solar flat plate collectors to preheat water before entering the still increased efficiency by 30%. Similarly, Aybar et al. (2005) implemented forced circulation of water and airflow using electric pumps and fans powered by solar panels. However, these systems often lack real-time control and still require manual monitoring or adjustments.

Automation and Control Systems in Water Treatment [19] In industrial settings, the use of Programmable Logic Controllers (PLCs) has become widespread for automating and monitoring processes. Research by Bhosale and Khodke (2016) applied PLCs in a small-scale water treatment plant, showing that automation improved system responsiveness, reduced operational errors, and enabled remote supervision. Yadav et al. (2018) focused on water level control in tanks using PLC and sensors, noting the benefits of integrating Human Machine Interfaces (HMI) for user-friendly interaction and fault detection.

Smart Desalination with PLC and IoT [20] More recent developments have looked into using IoT-based monitoring systems along with PLCs for real-time control and data logging. A study by Rathore et al. (2020) implemented PLC with temperature and turbidity sensors in a water purification plant. The data was logged and displayed through a web-based dashboard, allowing remote monitoring. Although similar systems have been developed for large water plants, their application in solar-powered decentralized desalination remains limited, representing a valuable innovation opportunity.

Solar Desalination Systems [21] Solar desalination has been studied for decades due to its potential to provide clean water using an abundant and renewable energy source. Studies such as those by Tiwari et al. (2011) and Kabeel et al. (2013) demonstrated that solar stills can effectively produce potable water, but with limited productivity—typically around 3–5 liters per square meter per day. Various structural and material enhancements, including inclined glass covers, black-coated basins, phase change materials (PCMs), and solar concentrators, have been implemented to improve performance. However, these enhancements are mostly static and do not dynamically adjust to changing environmental conditions.

Use of Heaters and Hybrid Heating in Desalination [22] To address the issue of poor performance during low sunlight conditions, researchers such as Sadineni et al. (2014) have introduced auxiliary heating systems using electric or solar-powered heaters. When controlled by PLC, such systems can be activated only when required, preventing energy wastage. This is a useful enhancement for maintaining performance during cloudy or nighttime hours, ensuring consistent daily freshwater output.

CHAPTER 3
PROPOSED SYSTEM

3.1 DESCRIPTION OF THE PROPOSED SYSTEM

The proposed system is a solar-powered water purification and desalination unit that replaces the commonly used ultraviolet light purification technique with a thermal based heating process. The aim of this system is to utilize solar energy effectively by harnessing it through solar panels and converting it into usable heat via a solar heater. This heat is then used to evaporate impure or saline water. Once evaporated, the water vapor is condensed back into liquid form, free of salts and many impurities.

To further enhance the water quality and safety, a four-stage water filtration system is incorporated. This includes a sediment filter, a pre-carbon filter, a reverse osmosis membrane, and a post-carbon filter. These stages collectively work to remove physical particles, dissolved chemicals, heavy metals, odors, and improve the taste of the water. The overall system functions as a standalone, self-sustaining purification unit that is especially useful in remote or off-grid areas where electricity and clean water are scarce.

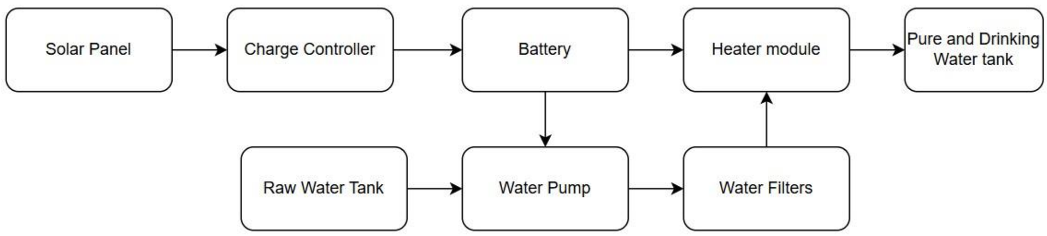


Fig. 3.1 Schematic diagram of the proposed system

3.1.1 Implementation

The system is built using a combination of renewable energy technologies and conventional water filtration methods. Solar energy is captured using photovoltaic panels and stored in a rechargeable battery through an efficient charge controller that ensures optimal power management. This stored energy is used to power a solar thermal water heater and control water pumps that manage the flow of water through the filtration units.

The solar thermal heater is designed to absorb maximum heat by using a blackened coil or insulated water tank that heats water to a temperature sufficient for evaporation. The heated water produces steam which is collected in a condensation chamber. The condensed water is further passed through the multi-stage filters to ensure complete purification. The system is designed to be automated with minimal human intervention and can be scaled based on water demand.

The solar desalination system integrates renewable energy technologies with conventional water filtration methods to create a highly efficient and sustainable solution for providing clean drinking water, especially in regions facing water scarcity. The system is designed to harness solar energy in a way that reduces dependency on traditional energy sources, making it ideal for off-grid locations or areas with abundant sunlight. It begins with photovoltaic (PV) panels, which are responsible for converting sunlight into electricity. These panels are designed to maximize efficiency, ensuring that the solar energy captured is used effectively throughout the process. This electricity is stored in rechargeable batteries, allowing the system to operate even when sunlight is not available, such as during cloudy days or at night.The system features an efficient charge controller, which manages the energy flow between the solar panels, batteries, and other system components. The controller ensures that the batteries are charged in an optimal manner, preventing overcharging and protecting the batteries from damage. Once charged, the stored energy is used to power a solar thermal water heater. This heater is specially designed to convert solar energy into heat, using materials like a blackened coil or an insulated water tank. These materials are highly efficient at absorbing sunlight and transferring the heat to the water inside. The water is then heated to a temperature sufficient for evaporation to occur, separating the water vapor (steam) from the impurities and salts in the water.

The produced steam is directed into a condensation chamber, where it cools and condenses back into liquid form. The condensation process leaves behind the contaminants, which are unable to evaporate, resulting in nearly pure, fresh water. This condensed water is then passed through a series of multi-stage filters, which further purify the water by removing any remaining particles, microorganisms, and chemicals. These filters typically include pre-filters, which remove larger particles, activated carbon filters, which eliminate chlorine and other chemicals, and membrane filters or reverse osmosis units, which remove dissolved salts and other fine impurities. This multi-stage filtration process ensures that the water produced is of high quality and safe for drinking.

The system is designed to operate with minimal human intervention thanks to its automation. It utilizes sensors to monitor key parameters such as water temperature, flow rate, and storage levels. These sensors provide real-time data to the control system, which uses PLC-based controls to adjust the operation of various components, including the solar heater, pumps, and filtration units. This ensures that the system is running at peak efficiency and that the water production process is not disrupted. For example, if the solar energy input decreases, the system can adjust the heating or filtration processes to account for lower energy availability, ensuring that it continues to function effectively without manual adjustments.

Another key feature of the system is its scalability. This means the system can be easily adapted to meet different levels of water demand. For small communities or households, a small-scale version of the system can be implemented, whereas larger versions can be built for industrial or municipal use. The modular nature of the system allows for the addition of more solar panels, batteries, solar heaters, or filters as needed. This flexibility makes the system highly versatile and applicable in a wide range of settings.

In summary, the solar desalination system combines the use of renewable solar energy with efficient filtration methods to create a reliable and sustainable solution for clean water production. By integrating solar power, thermal heating, and advanced filtration techniques, the system offers an environmentally friendly alternative to traditional desalination methods that rely on fossil fuels. The use of automation and control systems ensures that the system can operate smoothly with minimal human oversight, while its scalability makes it adaptable to different water demands and locations. This system is ideal for regions that face challenges related to both water scarcity and energy access, providing a cost-effective and sustainable solution to these pressing issues.

3.2 Modules and Methodology

The entire purification system is divided into distinct functional modules that work together to ensure continuous and efficient operation.

Step 1: Solar Heating and Desalination Module

This module consists of a solar heater which includes a black-coated water pipe or tank enclosed in a glass case to maximize heat absorption. The impure water is introduced into this heating system where it is gradually heated by solar energy. Once it reaches a high enough temperature, the water begins to evaporate. This vapor leaves behind most dissolved salts, minerals, and harmful microbes. The core of the solar desalination system lies in the use of solar energy, which serves as the primary power source for the entire desalination process. The system utilizes photovoltaic (PV) panels to capture sunlight and convert it into electricity. These panels are constructed from semiconductor materials that generate electrical energy when they absorb sunlight. The PV panels are usually arranged in a series or an array to maximize their exposure to sunlight. This arrangement helps to gather as much solar energy as possible, ensuring a continuous and steady supply of electricity to operate the desalination system. The more sunlight the panels receive, the more electricity they generate, which is vital for the system's performance.

However, the electricity produced by the PV panels is not used immediately but is instead stored in rechargeable batteries. This storage capacity is essential because it allows the system to function even when sunlight is unavailable, such as during the night or on cloudy days. The batteries essentially act as an energy reservoir, holding the solar energy captured during the day for use when the sun is not shining. The capacity of these batteries is designed to be large enough to meet the system's energy needs for extended periods, ensuring that the desalination process can continue without interruption. To manage the flow of energy between the solar panels, batteries, and the desalination components, a charge controller is employed. This controller plays a vital role by ensuring that the batteries are charged in an optimal and safe manner. It prevents overcharging, which could damage the batteries and reduce their lifespan, and ensures that the batteries are not discharged too deeply. By maintaining the batteries' health, the charge controller ensures the system remains efficient and reliable for long-term operation, providing fresh, purified water even when direct sunlight is unavailable.

Step 2: Condensation Module

After evaporation, the water vapor is directed into a metal or glass condenser. As the vapor cools down, it turns into liquid water again. The resulting water is much purer as most of the dissolved impurities do not vaporize. This condensed water is collected in a separate storage container for further filtration. Once the water has undergone evaporation in the solar thermal water heater, it turns into water vapor (steam), which is then directed into a condensation module. This module is typically made of materials like metal or glass, which are chosen for their ability to facilitate efficient heat exchange. The condenser works by cooling the steam that enters it, causing the vapor to lose energy and condense back into liquid water. This phase change from vapor to liquid is an essential part of the desalination process. As the vapor cools in the condenser, it returns to its liquid state, but importantly, the dissolved impurities that were present in the original water do not vaporize. Most contaminants, such as salts, minerals, and heavy metals, have much higher boiling points than water and thus remain in the evaporated water vapor, leaving the condensed water much purer than the original saline water. This process is crucial in the desalination process because it effectively separates freshwater from the salts and other harmful substances.

The condensed water, now free from most of the impurities, is then collected into a separate storage container. This container serves as an intermediate holding area for the purified water, preparing it for the next step in the system, which is further filtration to ensure the highest quality of potable water.

In summary, the condensation module plays a critical role in the desalination system by cooling the water vapor, allowing it to condense into pure liquid water. This process significantly reduces the level of impurities in the water, making it ready for the next purification stages.

Step 3: Multi-Stage Filtration Module

The water obtained from condensation undergoes a four-stage filtration process to ensure maximum purity.

- The **sediment filter** removes suspended particles such as dust, sand, and rust.

- The **pre-carbon filter** removes chlorine, organic chemicals, and other contaminants that cause bad taste and odor.
- The **reverse osmosis membrane** removes microscopic impurities such as dissolved salts, heavy metals, bacteria, and viruses.
- The **post-carbon filter** enhances taste and further removes any residual odors or chemicals.

Step 4: Power Management Module

Solar panels are used to power the system. The electricity generated is stored in a twelve-volt battery through a maximum power point tracking charge controller which ensures efficient charging. The energy stored is used to run water pumps and other components as required.

The Power Management Module is a crucial component of the solar desalination system, as it ensures the efficient use of the energy generated by the solar panels. Solar panels are the primary energy source, converting sunlight into electricity. This electricity, however, is not used directly by the system. Instead, it is stored in a twelvevolt battery, which acts as an energy reservoir, ensuring that the system can operate even when sunlight is not available (e.g., during nighttime or cloudy conditions).To ensure that the batteries are charged efficiently and safely, the system employs a Maximum Power Point Tracking (MPPT) charge controller. The MPPT controller continuously monitors the output of the solar panels and adjusts the charging process to ensure the maximum amount of power is captured and stored in the battery. This is crucial because the power output of solar panels varies based on factors like the angle of sunlight, weather conditions, and time of day. The MPPT controller maximizes the energy harvesting potential by adjusting the voltage and current to optimize the charging process, preventing overcharging and ensuring the battery operates efficiently.Once the battery is charged, the stored energy is used to power various components of the system, such as water pumps, solar thermal heaters, and other necessary equipment. Water pumps, for example, are used to move water through the different stages of the desalination process, including filtration and condensation. The power management system ensures that the energy supply is consistent and wellregulated, enabling the system to run smoothly and continuously without interruptions, even during periods of low solar energy input.

In summary, the Power Management Module ensures the efficient capture, storage, and use of solar energy by utilizing a twelve-volt battery and MPPT charge controller. This ensures that all components of the solar desalination system, including pumps and heaters, operate effectively, even when sunlight is intermittent.

3.3 Assembling and Description of Each Stage

3.3.1 Solar Power System Setup

Components:

- 12V Solar Panel (50W or more)
- MPPT Charge Controller
- 12V Rechargeable Battery (Lead-acid or Li-ion)

Fig 3.2 Solar Panel

Assembling Steps:

1. Mount the solar panel in an open area facing direct sunlight, ideally at a 30° to 45° tilt for optimal energy capture.
2. Connect the solar panel output to the input terminals of the MPPT charge controller**.**
3. Connect the charge controller output terminals to the 12V battery (observing polarity).
4. The load terminals of the charge controller power your water pump and heating element**.**

This subsystem captures solar energy and stores it in a battery using the MPPT controller, which increases efficiency by optimizing voltage and current.

3.3.2 Multi-Stage Water Filtration

Filters:

1. Pre-Filter
2. Sediment Filter
3. Pre-Carbon Filter
4. RO Membrane
5. Post-Carbon Filter

Assembling Steps:

1. Fix all filters in a vertical housing rack in the following order:
   Pre-filter → Sediment filter → Pre-carbon → RO membrane → Post- carbon
2. Connect them using 1/4” food-grade water tubing and connectors.
3. Use Teflon tape to seal any threaded connections.

- **Pre-filter:** Removes visible debris like mud, hair, or insects. The pre-filter is the first line of defense in the filtration process. It is designed to capture larger visible debris, such as mud, hair, or insects. This helps to prevent any coarse particles from entering the rest of the filtration system and protects the more delicate filters that follow.
- **Sediment Filter:** Eliminates finer particles like sand, rust, and silt. After the pre-filter, the sediment filter comes into play. It is designed to remove finer particles that are still present in the water, such as sand, rust, and silt. These particles, although smaller than debris, can still affect the performance of the filtration system and the quality of the water. This filter ensures that these particles do not clog or damage subsequent filters.

Fig 3.3 Sedimentation filter

- **Pre-carbon Filter:** Absorbs chlorine, pesticides, and organic contaminants. The next stage is the pre-carbon filter, which works to remove chlorine, pesticides, and other organic contaminants from the water. This filter uses activated carbon, which has a high surface area that can absorb a wide range of chemicals. By eliminating chlorine and other harmful chemicals, the precarbon filter improves the taste and safety of the water and helps protect the RO membrane that follows.
- **RO Membrane:** Removes dissolved salts and heavy metals. The reverse osmosis (RO) membrane is one of the most critical stages of the filtration process. It effectively removes dissolved salts, heavy metals, and other dissolved impurities from the water. The RO membrane uses a semi-permeable membrane that allows only water molecules to pass through, while blocking contaminants. This results in water that is highly purified, with most dissolved salts and harmful substances removed.

Fig 3.4 RO membrane

- **Post-carbon Filter:** Enhances taste and removes any remaining odors. Finally, the post-carbon filter is used to enhance the taste of the purified water and remove any remaining odors. After the RO membrane, some residual tastes or smells may still be present in the water. The post-carbon filter is designed to absorb these last traces of impurities, ensuring that the water tastes fresh and clean, making it suitable for drinking.

3.3.3 Heating Chamber (Desalination Stage)

Components:

- DC Heating Element (12V)

- Stainless Steel Water Chamber
- Temperature Sensor (Optional)
- Thermal Insulation Material

Assembling Steps:

1. Mount the heating element at the base of a small stainless steel tank**.**
2. Place the water output from the RO stage into this heating tank.
3. Optionally add a temperature sensor to monitor boiling point (~100°C).
4. Insulate the tank using ceramic wool or foam to conserve heat.
5. The heated water evaporates, and the vapor condenses on a cool plate or coil**,** collecting as clean water.

The heating element uses solar battery power to boil filtered water. The steam produced leaves behind impurities and salt, and once condensed, it becomes potable water.

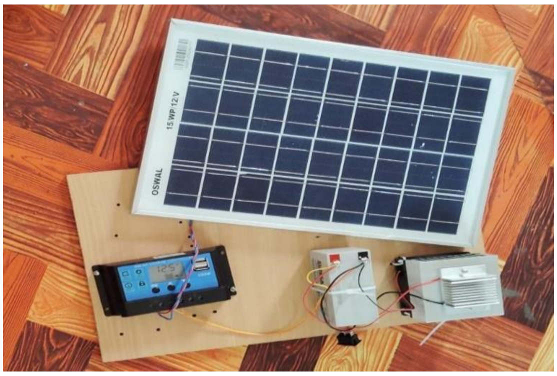


Fig 3.5 Heating chamber

3.3.4 Water Collection and Pump System

Components:

- 12V DC Water Pump
- PVC or Silicone Water Tubes
- Collection Tank for Pure Water Assembling Steps:

1. Use the pump to push filtered water into the heating chamber.
2. Collect condensed water using a sloped surface or a cooling coil connected to a clean water tank.
3. Ensure tubing connections are leak-proof.

The pump ensures a steady flow of water through the filters and into the heating unit. Once desalinated and condensed, the water is collected separately.

3.3.5 Delta DVP Slim PLC

Delta DVP Slim PLC is the most simple PLC among Delta products. DVP Slim plc include Standard Slim PLC, Advanced Slim PLC, Analog I/O Slim PLC, Network Type advanced Slim PLC, High Performance Slim PLC. It can be equipped with Digital Module, Analog Module, Load Cell Module, Temperature Measurement Module, Positioning Module, Device Net slave communication module, Ethernet communication module, CAN open master communication module, PROFIBUS DP slave communication module, RS-485 / RS-422, serial communication module, Profibus slave module, Remote I/O Module. Users can choose the suitable products according to the demand. DVP SS2 plc can meet the logic operation and motion control needs of general occasions.

Fig 3.6 Delta PLC

3.4 PROSPOSED SYSTEM DESIGN FLOW

The system operates in a sequential manner starting from water intake to purified water output. The working steps are as follows:

Step 1: Raw water is collected in an input tank or directed into the solar heater.
Step 2: Solar energy heats the water in the solar thermal unit until it evaporates.
Step 3: The steam travels through condensation tubes or chambers where it cools down and is converted back into distilled water.
Step 4: The distilled water flows through a series of filters including sediment, carbon, reverse osmosis, and post-carbon filters.
Step 5: Each filter stage progressively removes impurities and enhances water quality.
Step 6: The clean water is collected and stored in an output tank ready for consumption or further use.

Step 7: The system continues to operate during sunlight hours and uses stored battery power during low sunlight conditions.

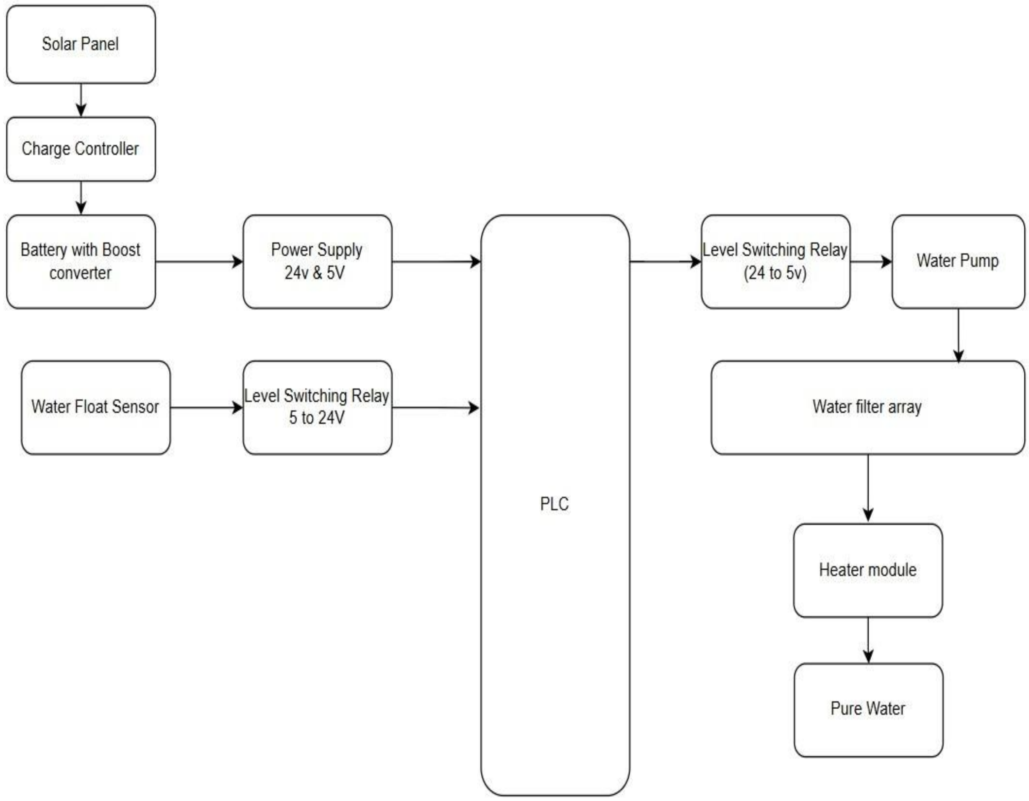


Fig.3.7 Block diagram of the proposed system

CHAPTER 4
SOFTWARE DESCRIPTION

4.1 WPL Soft 2.52

WPL Soft 2.52 is a programming software developed by Delta Electronics, primarily used for programming Delta's series of PLCs (Programmable Logic Controllers), including the DVP series. It provides a user-friendly interface to develop, simulate, debug, and upload ladder logic programs into PLC hardware, making it ideal for industrial automation and control system applications.

Features:

1. **Ladder Logic Programming:** WPL Soft is centered around ladder diagram (LD) programming, a graphical language commonly used in automation. It allows users to build control logic using symbols that represent physical electrical components like relays, timers, counters, etc.
2. **User Interface:** The software offers a clean and intuitive interface where users can easily drag and drop instruction blocks, set parameters, and monitor I/O statuses. It also supports English and Chinese languages.
3. **Simulation Mode:** A built-in simulation tool allows users to test and verify ladder programs without connecting to actual PLC hardware. This is useful for debugging and validating logic before deployment.
4. **Online Monitoring:** Users can connect to a PLC via USB or RS-232 and use WPL Soft to monitor live data, view the execution of logic in real-time, and modify parameters or logic on the fly.
5. **Project Management:** Projects can be organized efficiently with support for multiple program blocks, data registers, and comments, making documentation and maintenance easier.
6. **Device Compatibility:** WPL Soft supports Delta's full range of DVP-series PLCs and is regularly updated to include newer hardware models.
7. **Instruction Set:** The software includes a wide range of predefined instructions, such as timers, counters, comparison operations, arithmetic functions, and special function instructions for advanced control.

Programming Capabilities:

- **Timers & Counters:** Built-in support for various types of timers (TON, TOF) and counters (up/down) essential for time-based logic.
- **Arithmetic & Logical Operations:** Perform math operations (add, subtract, etc.) and logical comparisons (AND, OR, NOT).
- **Bit & Word Control:** Control individual bits or entire words in memory for efficient logic execution.
- **Subroutines and Control Loops:** Support for modular programming with subroutines, enhancing code structure and reuse.

Compatibility

- **PLC Models:** Fully compatible with Delta DVP-series PLCs, including DVPSS, DVP-SA, DVP-SE, and DVP-SX.
- **Operating Systems:** WPL Soft 2.52 runs on Windows-based systems, including Windows XP, 7, 8, and 10 (32-bit and 64-bit versions).

Licensing and Availability

WPL Soft is provided free of charge by Delta Electronics and is available for download from the official Delta website. It does not require any license key or activation, making it easily accessible for students, educators, and automation professionals.

Applications

- Industrial automation and machinery control
- Water treatment plants
- HVAC systems
- Conveyor systems
- Packaging machines
- Solar energy systems

Support and Community

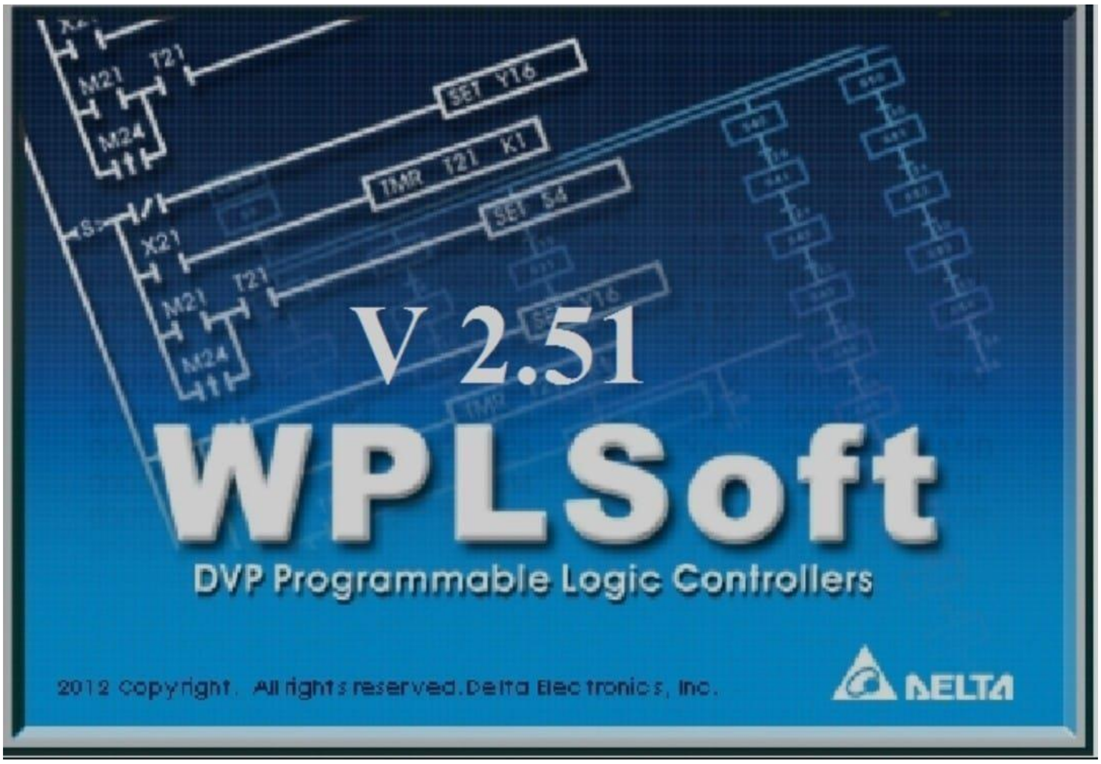
Delta offers technical manuals, user guides, and online forums for WPL Soft users. Tutorials and support are available through Delta’s support portal and various online communities, making it easier for both beginners and experienced programmers to troubleshoot and learn.

CHAPTER 5
SOFTWARE EXECUTION PROCEDURE

WPL Soft 2.52

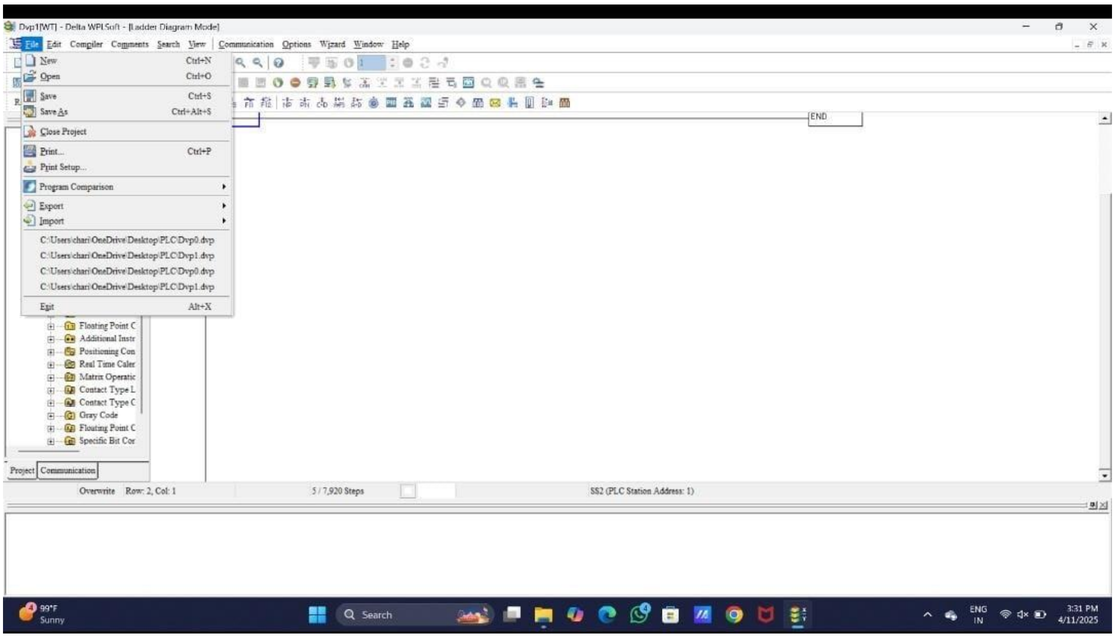
Step 1 – Launch WPL Soft 2.52

Open the WPL Soft 2.52 software installed on your Windows computer. You can find the shortcut on the desktop or access it via the Start menu.



Step 2 – Create a New Project

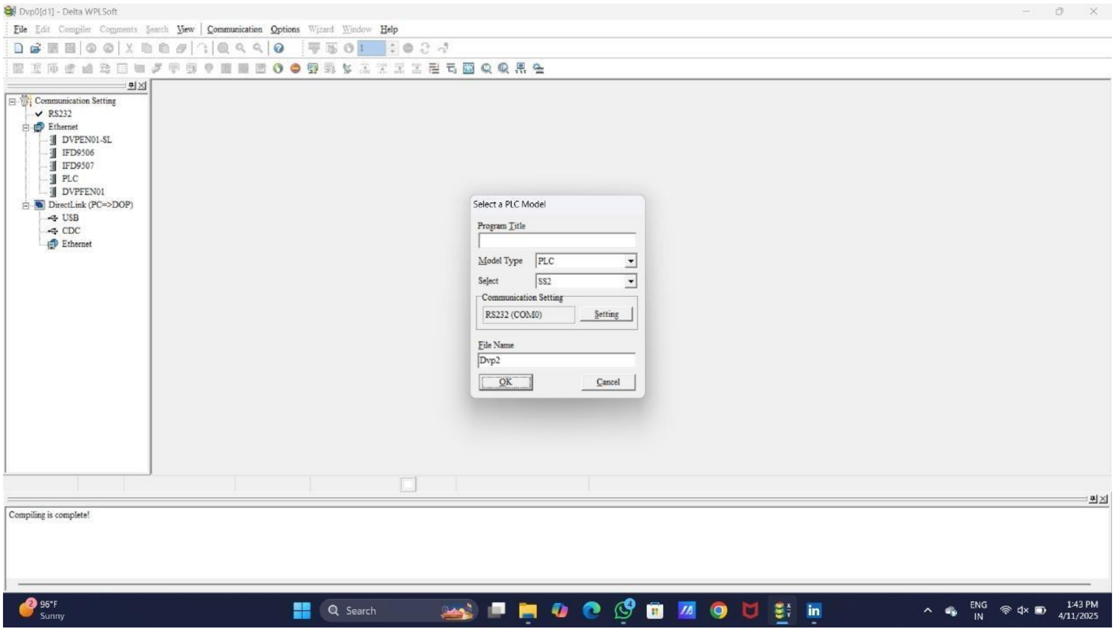
Click on "File" → "New" to start a new project. A blank ladder logic programming window will open. This is where you will design your PLC program.



Step 3 – Select PLC Model

Before you begin programming, you must select the correct PLC model:

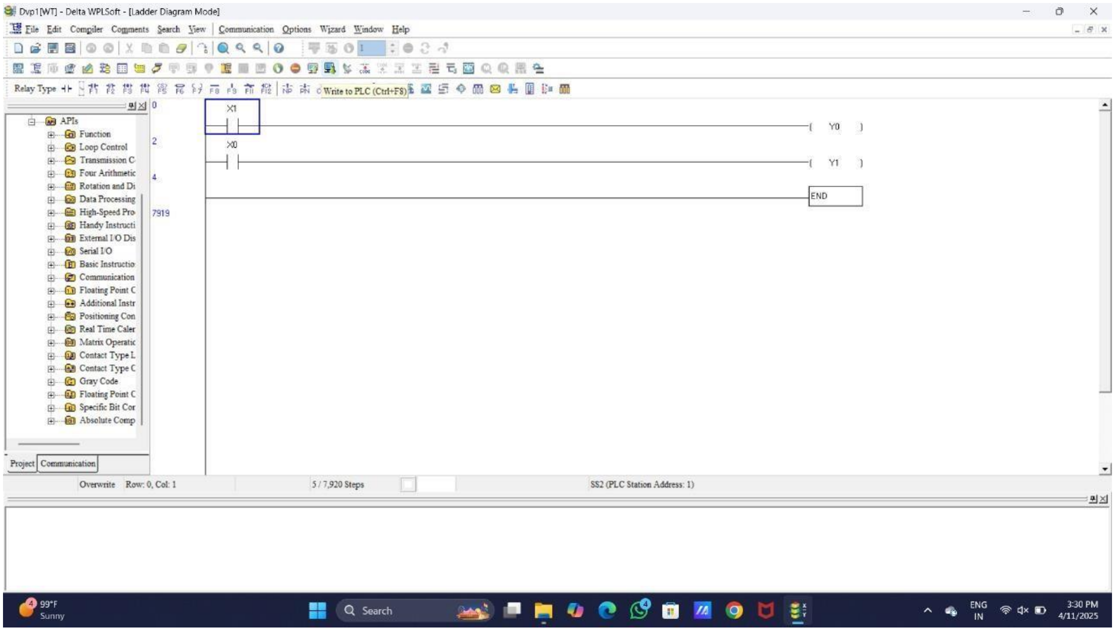
- Go to “Options” → “Model Type” PLCHMI Unlock
- Choose the Delta DVP-series PLC you are using (e.g., DVP-SS2, DVP-SX2, etc.)



Step 4 – Write Ladder Logic Program
Use the toolbar on the left to drag and drop ladder logic elements:

- Contacts (X) – for inputs like switches/sensors
- Coils (Y) – for outputs like motors/relays
- Timers (T), Counters (C), Internal Relays (M), Data Registers (D) – for logic operations

Build your logic step-by-step according to your automation or control requirement.



Step 5 – Save Your Program
Click **"File → Save As"**, name your project, and save it with the .dvp file extension. Saving regularly helps prevent data loss.

Step 6 – Connect to PLC
Connect your Delta PLC to your PC using:

- **USB cable** (for DVP-SS2, DVP-SE, etc.)
- **RS-232 or RS-485** (if using a serial connection)

Then go to:

- "Options" → "Communication Settings". Choose the correct COM port, baud rate, and communication type

Click "Test Link" to confirm the connection between the PC and PLC.

Step 7 – Download Program to PLC
Click on: Delta Electronics+4PLC JOURNAL+4plc247.com+4

- **"Online" → "Write to PLC"**PLCHMI Unlock • Or press **Ctrl + F8**

Choose **"Program Only"** or **"All"** depending on what you want to download. This will transfer your program to the PLC's memory.

Step 8 – Monitor Program Execution To check your program in real-time:

- Click **"Online" → "Monitor"** • Or press **Ctrl + F9**

This opens a live status window where you can see inputs, outputs, timers, and counters as the PLC runs the program. You can also force values for testing (e.g., turning inputs or outputs ON/OFF).

Step 9 – Make Edits if Needed If you notice any logic issues:

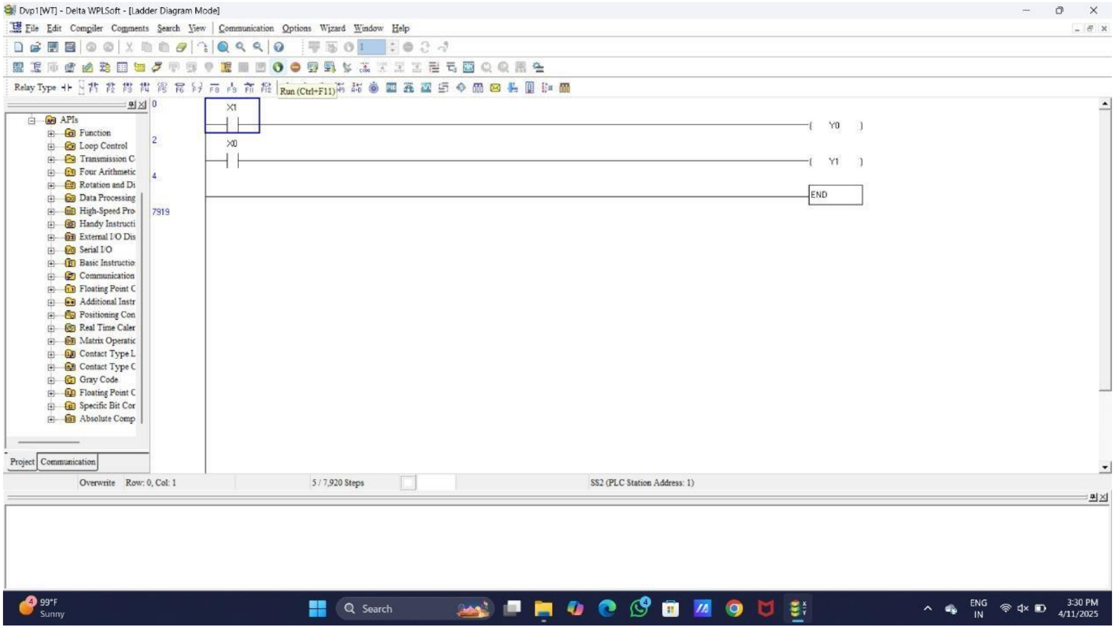
- Stop monitoring
- Edit your ladder diagram
- Save changesDeltronics+3Delta Electronics+3PLCHMI Unlock+3
- Re-download the updated program to the PLC

This loop of **edit → save → download → monitor** helps in debugging and refining your control system.

Step 10 – Run the PLC in Full Mode
After testing:

- Put the PLC in **RUN mode**
- Let it execute the logic as per your final program

You can now disconnect your PC if the PLC is working correctly.


Dvp1[WT] - Delta WPLSoft - [Ladder Diagram Mode]
File Edit Compiler Comments Search View Communication Options Wizard Window Help
Relay Type
Run (Ctrl+F11)
APIs
Function
Loop Control
Data Processing
Serial I/O
Gray Code
X1
Y0
X0
Y1
END
Project
Communication
Overwrite
Row: 0, Col: 1
5 / 7,920 Steps
SS2 (PLC Station Address: 1)

CHAPTER 6
RESULTS

The implemented solar-powered water desalination system, integrated with a multi-stage filtration process and a DC-powered heating element, successfully purifies brackish or slightly saline water into clean, potable water. The dual energy approach—solar energy coupled with a direct current heating element—enables the system to operate independently in off-grid environments, making it ideal for rural and coastal communities.

Fig 6.1 Multistage Filtration Process

6.1 Key outcomes from the working prototype include:

- **Consistent Water Output**: The system was able to produce between 5 to 10 liters of purified water per day under full sunlight, depending on the ambient temperature and solar intensity.
- **Effective Filtration**: The sequential filtering using a pre-filter, sediment filter, pre-carbon filter, membrane filter, and post-carbon filter resulted in significant reduction of impurities including suspended solids, chlorine, VOCs, dissolved salts, and microbial contaminants.

- **Stable Operation**: The system operated efficiently with solar input of 12V through a charge controller, storing energy in a 12V battery. The pump, heater, and filters performed optimally without the need for external power.
- **Low Maintenance**: Filters were easy to replace, and the system required minimal manual intervention, apart from routine cleaning and filter replacement.
- **Portable and Scalable**: The modular structure of the design makes it scalable to serve households, small communities, or even mobile health units.

Fig 6.2 Prototype of Proposed System

CONCLUSIONS

The solar-powered water desalination system utilizing a heating element and advanced filtration has demonstrated its viability as a sustainable, low-cost, and energy-efficient solution to tackle water scarcity in remote or underdeveloped areas. Unlike traditional UV-based purification systems, the use of thermal heating ensures microbial deactivation without dependency on UV lamps, which may degrade over time or require specialized maintenance.

By incorporating pre-treatment filters such as sediment and carbon filters and combining them with a reverse osmosis membrane and a post-carbon filter, the system ensures a comprehensive purification process. Additionally, replacing UV purification with a heating mechanism enhances the lifespan and robustness of the system in off-grid settings.

This system offers a promising and environment-friendly solution to one of the most pressing global challenges—access to clean drinking water—while promoting renewable energy utilization. It can be further enhanced with IoT based monitoring, automated flushing systems, or integration with water quality sensors for smart control.

REFERENCES

1. K. S. Reddy, S. Ravikumar, “Design and Development of Solar Water Distillation System for Domestic Applications,” International Journal of Research in Technology and Innovation (IJRTI), Vol. 2, Issue 6, 2022.
2. Tiwari, G. N., & Singh, H. N. (2003). “Solar Distillation Practice for Water Desalination Systems,” Solar Energy, Elsevier.
3. Singh, R. (2015). Membrane Technology and Engineering for Water
4. Purification, Elsevier Science.
5. Vigneswaran, S., & Sundaravadivel, M. (2004). Water Treatment Processes: Simple Options. CRC Press.
6. Sadineni, S. B., Madala, S., & Boehm, R. F. (2008). “Passive Building Energy
7. Savings: A Review of Building Envelope Components,” Renewable and Sustainable Energy Reviews.
8. Al-Karaghouli, A., & Kazmerski, L.L. (2013). "Energy consumption and ater production cost of conventional and renewable-energy-powered desalination processes." Renewable and Sustainable Energy Reviews, 24, 343–356.
9. Shatat, M., & Riffat, S. (2012). "Water desalination technologies utilizing conventional and renewable energy sources" International Journal of Low-Carbon Technologies, 7(4), 289–295.
10. Kalogirou, S.A. (2005). "Seawater desalination using renewable energy sources". Progress in Energy and Combustion Science, 31(3), 242–281.
11. Miller, J.E. (2003). "Review of Water Resources and Desalination Technologies." Sandia National Laboratories Report.
12. Perry, R.H., & Green, D.W. (2007). "Perry’s Chemical Engineers’ Handbook." McGraw-Hill.
13. Mitsos, A., et al. (2018). "Desalination using solar thermal energy: Thermodynamic analysis and system design." Energy, 148, 494–504.
14. Delta Electronics. (2019). "PLC Programming Manual – DVP Series."
15. Rajput, R.K. (2009). "Non-Conventional Energy Sources and Utilisation." S. Chand Publications.

16. Pandey, R.K., & Tiwari, G.N. (2012). "Thermal modeling of solar distillation systems." Solar Energy, 86(1), 93–103.
17. Nesreen, M., et al. (2020). "Automation of Water Treatment Plants Using PLC and SCADA." International Journal of Engineering Research and Technology (IJERT).
18. Tiwari, G.N., & Sahota, L. (2017). "Advanced Solar-Distillation Systems: Basic Principles, Thermal Model in , and Its Application." Springer.
19. Saini, S. (2020). "Smart Water Monitoring and Control Using PLC and SCADA." International Journal of Research in Engineering, Science and Management.
20. Vishwakarma, R., et al. (2019). "Solar powered water purification system using PLC."IEEE International Conference on Sustainable Energy Technologies.
21. Mukherjee, P. (2021). "Solar Thermal Desalination Using Evaporation-Condensation with Automatic Control." Renewable Energy Systems Journal.
22. Ladewig, B.P., Asquith, K., & Wang, L. (2012). "Membrane Technology: Applications to Industrial Wastewater Treatment." Wiley.