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DESIGN AND DEVELOPMENT OF A SMART CONTROL SYSTEM TO SUPPLY SUSTAINABLE ENERGY TO A REFUGEE CAMP

M.Sc. Thesis by

Ahmed KASAPBAŞI

Department of Electrical and Electronics Engineering

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We have read the thesis entitled **"DESIGN AND DEVELOPMENT OF A SMART CONTROL SYSTEM TO SUPPLY SUSTAINABLE ENERGY TO A REFUGEE CAMP"** completed by **AHMED KASAPBAŞI** under the supervision of **PROF. DR. HÜSEYİN CANBOLAT** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

Prof. Dr. Hüseyin CANBOLAT

Supervisor

Prof. Dr. Şerafettin EREL

Jury Member

Assoc. Prof. Dr. Mehmet DEMİRTAŞ

Jury Member

Prof. Dr. Ergün ERASLAN

Director

Graduate School of Natural and Applied Sciences

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Name & Surname: Ahmed KASAPBAŞI

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DESIGN AND DEVELOPMENT OF A SMART CONTROL SYSTEM TO SUPPLY SUSTAINABLE ENERGY TO A REFUGEE CAMP

ABSTRACT

War regions suffer from lacking of all the elements of life because of conflicts, so they become unsafe places to live and people flee to save their lives and are forced to live in camps that suffer from the lack of many services, including electricity.

In this thesis, it is suggested and developed a smart control system for distribution, monitoring, controlling and supervision to supply the electrical power in one of the proposed refugee camp which is supposed to be beside one of the rivers that is near from the Syrian-Turkish border. The generated power depends on clear, cheap and sustainable resources like water, solar and wind. The main power source in the studied system is hydro power that is generated from flow of river by using a new hydro power technics without need to build dams, but the generated hydro power sometimes is not enough, for that it is suggested to be supported with other sustainable energy sources like solar and wind. The proposed control system works according to a new strategy which aim to exploit the whole generated power from the sustainable energy sources at time of its existence without wasting a lot of it and the extra power is stored or used in other useful tasks.

The suggested control system depends on Supervisory Control and Data Acquisition (SCADA) system which uses a logic controller, sensors and transducers for performing the required task. The design of control system is achieved by using programs that have ability to represent, emulate and test the system programmatically before applying as a hardware. Thus, that saves the time and money. This operation of control will provide the supposed camp with reliable and sustainable energy and exploit the generated power optimally.

Keywords: SCADA, sustainable energy, logic controller, refugee camp.

BİR MÜLTECİ KAMPINA SÜRDÜRÜLEBİLİR ENERJİ SAĞLAMAK İÇİN AKILLI BİR KONTROL SİSTEMİNİN TASARIMI VE GELİŞTİRİLMESİ

ÖZ

Savaş bölgeleri çatışmalardan dolayı yaşamın tüm bileşenlerinin eksikliğinden muzdaripdir. Bu yüzden bu savaş alanları yaşamak için güvenli olmayan yerler haline gelir. İnsanlar hayatlarını kurtarmak için kaçarlar ve elektrik de dahil olmak üzere pek çok hizmeti olmayan kamplarda yaşamak zorunda kalırlar. Bu yüksek lisans tezinde, önerilen mülteci kamplarından birine elektrik teminini sağlamak, izlemek, kontrol etmek ve denetlemek amacıyla akıllı bir kontrol sistemi önerilmiş ve geliştirilmiştir. Önerilen kamp, Suriye-Türkiye sınırına yakın bir nehrin yanında inşa edilmiştir. Çalışılan sistemde birincil enerji kaynağı, baraj inşa etmeye gerek kalmadan nehir suyu akışından enerji üretmek için yeni bir teknik kullanarak üretilen enerjidir. Bununla birlikte, hidroelektrik enerji bazen yetersiz kalabilir, bu nedenle hidroelektrik enerjisinin güneş ve rüzgar gibi diğer enerji kaynaklarıyla desteklenmesi önerilmektedir. Önerilen kontrol sistemi, enerji kaynaklarından elde edilen enerjinin tamamını bu enerjiyi en verimli şekilde kullanmayı hedefleyen yeni bir stratejiye göre çalışır. Aşırı kapasite başka faydalı işlerde kullanılabilir veya saklanabilir. Önerilen kontrol sistemi, bir SCADA sistemine dayanmaktadır, gerekli görevi gerçekleştirmek için sensörler ve dönüştürücüler kullanır. Kontrol sisteminin tasarımı, sistemi kurmadan önce simülasyonu kullanarak sistemi modelleme, simüle etme ve test etme becerisine sahip ve bu nedenle zaman ve para tasarrufu sağlayan bir yazılım kullanılarak gerçekleştirilir. Kontrol süreci mülteci kampına sürdürülebilir, güvenilir enerji sağlar ve üretilen enerjiyi en iyi şekilde kullanır.

Anahtar Kelimeler: SCADA, sürdürülebilir enerji sistemi, mantıksal denetleyici, mülteci kampı.

CONTENTS

NOMENCLATURE

Acronyms

SCADA	Supervisory Control And Data Acquisition
HMI	Human Machine Interface
PLC	Programmable Logic Controller
AC	Alternative Current
DC	Direct Current
MPP	Maximum Power Point
LD	Ladder Diagram
SFC	Sequential Function Charts
ST	Structured Text
ILs	Instruction Lists
FBD	Function Block Diagram
RTU	Remote Telemetry Unites
FF	Fill Factor
ηPV	Module Efficiency
IGs	Induction generators
PV	Photovoltaic
I_{sc}	Short-circuit current
V_{oc}	Open Circuit Voltage
I_{mp}	Maximum power operating current

V_{mp}	Rated maximum power voltage
P_{mp}	Maximum power
WTG	Wind turbine generator technologies.
DFIG	Double Fed Induction Generator.
PMSG	Permanent Magnet Synchronous Generator.
ICS	Industrial Control System
MTU	Master Terminal Unit
IED	Intelligent Electronic Device
DI	Digital Input.
DO	Digital Output.
AI	Analog Input.
AO	Analog Output.
OIT	Operator Interface Terminal
FPGA	Field Programmable Gated Array
PS	Power supply
CPU	Central processing unit
IMs	Interface modules.
SMs	Signal modules.
FMs	Function modules
CPs	Communications processors
DOE	Department of Energy

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CHAPTER 1

INTRODUCTION

Several researches studied the incorporation among power sources and design microgrid to produce energy via the utilization of various kinds of external and internal energy control technologies for production, transmission and distribution the energy. This chapter will give a wide study of literature survey.

1.1 Literature Summary

Raju K Padma (2012), he/she suggested a new way for simulating, managing, and monitoring a sustainable energy sources that depend on crossbred energy system model._XPC target software is used for simulating the system in real time and the SIMULINK is utilized for developing the model. He/She suggested to use a PLC, which deal with the model with the help of the Data acquisition board, for performing the control action and the energy management of the system. İn addition to suggestion of SCADA system that achieves the several tasks like human machine interfacing, the real time, alarm handling, monitoring, data and event logging. Not only that but also for clarifying the several cases of crossbred energy system the simulation is tried for load changes and the meteorological. Moreover, the suggested simulation permits the client to operate the model in real time for longer periods, analyze the dynamics of the system and hence designing the suitable control system, and to experiment the precision of the improved control algorithm on the real microgrid which will be economical , robust and secure due to all these working together [1].

LI Guangming (2009), he introduced an on-grid solar/wind crossbred energy system which is achieved by the energy management and control subsystem that are constructed as hardware. Moreover, he found that it is depended on the multi-factors theory in the crossbred energy system, for that the control subsystem is considered as a factor. In addition to he suggested the components of this control subsystem which include human-machine interface (HMI), RS485/TCP converter, programmable logic controller (PLC), DC electric power meters, AC multi-function electric power meters, grid-connected control module, etc. These components is used for managing and controlling the system of multi-sources, like solar, wind, storage batteries, power grid and loads, not only that but also for communicating with others and gathering data. This search focuses on the hardware part, the communication of system components each other and the way of meeting its functions and demands. Finally, it show depending on experiments that this type of systems is suitable for both on-grid and off-grid mode [2].

Wang Li and Hua Kuo (2007), in this search it is suggested a new control and monitoring system for performing real-time control and observing a crossbred PV-wind-battery sustainable power system. A supervisory control and data acquisition (SCADA) system that employs campus network of National Cheng Kung University integrated with both digital power meters and a programmable logic controller (PLC) make up the suggested system. Moreover, this system has ability for measuring the real time parameters of electrical data which can be efficiently sent to a far observing center by utilizing intranet. The proposed PV-wind-battery system includes a PV module, two wind induction generators (IGs), a battery unit, a DC-to-AC inverter and an AC-to-DC converter. A new controller of the PLC is also suggested to switch excitation capacitors of the induction generators (IGs) to control the power factor of the induction generators(IGs) and performance of output voltage. At the end of this search is deduced from the empirical results which are depended on simulation that the suggested control and observing system can perform real-time data acquisition and supervisory control of far several forms of sustainable power system [3].

Ortjohann Egon (2007), it is tested a proposed system connotation of crossbred energy systems with an output energy bigger than 20 kW according to stability and feasibility in this study. The system is simulated encompassing an advanced management and control software. This software is sent to a soft PLC on an manufacturing PC and the whole system was installed in hardware. Under laboratory conditions, a group of experiments have been implemented and the system was tried on awide range. The results clarify that the suggested system connotation is suitable. The constructed crossbred energy system enables all features of the modular system construction. The major elements (power sources, converters and inverters) are capable to be hot plugged. This indicates that during full operation mode of system these elements can be removed, plugged in again and exchanged. Defect elements can be exchanged speedly and simply without occuring any upsets. Moreover, the whole system can be simply extended without occuring changes in the structure of system and available major hardware elements. The utilized norm manufacturing elements introduce low costs, high availability, easy maintenance and high reliability across high agreed and advanced technologies. At the end of search, the executed system achieved all features of the modular system construction and applied standardized manufacturing elements. Moreover, ameliorations of the PLC cycle speed, the precision of the simulation models and the mensuration elements to improve the effectiveness are still in execution [4].

Soetedjo Aryuanto (2014), Web-SCADA system was executed on the crossbred PV-wind energy system in this search. Both the environment parameters like PV temperature, solar irradiation and wind speed and the electrical paramaters like power, current, and voltage are observed from far a distance by means of a web browser which is connected with internet. The SCADA system permits the client to control the crossbred energy system from far a distance. The SCADA system is implemented by developing PLC, RTUs and the low cost sensor systems. The used Web-SCADA software in this research is the IntegraXor SCADA which supplies a simple way for improving the Web-based SCADA implementations. The Web-SCADA functions duly in the controlling and observing the crossbred energy system according to the experimental results. The improved RTUs are capable to gather the sensor data and connect with the SCADA server in real-time. The improved sensor systems supplies the rate of error of 2.87% [5].

AL-BAJALAN Sadeq Mohammed Ameen Saeed (2016), A power management system was suggested in this search to improve the energy of water station in Garmian (Iraq). A new way was offered for dominating of the flow of energy in the micro-grid. The suggested way contains the main five elements of microgrid like power sources (PV-Battery), control elements, storage devices, point of common coupling and loads. The aim of design of this system is supplying continous high-quality energy to critical loads in the specific place. For achieving the aim from this system, a model was designed, improved and simulated by MATLAB/Simulink programming. Moreover, an external controller was utilized for designing a smart energy management of water plant that are existed at Garmian region in Iraq [6].

Joga Rao G. (2016), one of the main popular interests of the uses is to decrease the emissions from conventioal energy stations by utilizing clean power and to decrease the high price of providing electricity to far regions. Crossbred energy systems can supply a good way for such troubles because they combine clean power along with the conventional energy stations. Crossbred systems are distinguished by including two or more technics of electrical production, for optimizing global efficiency of the operations. Essentially this system includes the combination of hydroelectric, wind and solar system with battery storage device that will supplies continuous energy. Wind turbines are utilized for transforming wind power and solar panels are utilized for transforming solar power into electricity and hydroelectric system is utilized for production of electricity from kinetic power of the water. The model has patterned to supply energy quality for mixed clean power systems. In this study, the modeling of mixed solar photovoltaic, wind and hydro power system with battery storage are done by utilizing MATLAB/SIMULINK software and results are offered [7].

Dhongade Vipul, Shaligram A.D. (2018), PLC-SCADA (Programmable Logic Controller, Supervisory Control and Data Acquisition) system is suggested with crossbred sustainable power system to perform effective power production, storage and observing where is used this system for electric vehicles at far charging plants. The utilization of sustainable power sources is the main agent which promotes production of clean power all over the world. The traditional power sources are running out gradually because of its continuous consumption all over the world. The suggested study specifies strategy to combine several crossbred clean power sources, like biomass,solar power and wind energy and for continuous generation of clean power and monitoring target. The suggested industrial controller PLC, which all source are combined by utilizing power line transducer, is used for measuring the produced energy from crossbred clean energy system and is monitored with utilizing the SCADA system. The main feature of crossbred clean power system is the utilization of produced power to charge electric vehicles at any far positions. The suggested design can be simply executed to observe energy from crossbred clean power sources and works to deliver clean energy as per load request [8].

Delimustafic Dada (2011), in this study, a design of a crossbred sustainable power system is proposed. The introduced design suggests to be operated the next parts: a solar energy station a pumped-storage hydro energy station and a wind energy station. Since the pumped-storage hydro energy station is considered the most complicated structure of the crossbred sustainable power system, it is especially focused on its two control loops: The load-depended frequency control loop and the water tank level control loop. The effective controller is designed and implemented by the means of models of these control loops. A switch logic construction has been improved for reliable energy equipping of the users and performing efficient power distribution. In addition the performances of three kinds of energy converters are studied because the final power generation of crossbred sustainable power system extremely relies on the operation of power conversion. This encompasses the parameterization, modelling and simulation for these converters. Finally, the designed and suggested SCADA system includes a graphical user interface (GUI) which its tasks are data monitoring, supervision and control. The suggested design of crossbred sustainable power system is considered the base of the system execution which strives at serving as a platform for education, researches, studies and a wide group of projects on sustainable power [9].

Qi Wei (2011), this search aims for the improvement of a supervisory model predictive control way for the optimal management and running of crossbred standalone solar-wind power production systems. The supervisory control system is designed by means of model predictive control that calculates the energy references for the solar and wind subsystems at every sampling period while decreasing a proper cost function. Two local controllers recieves the energy references for driving the two subsystems to the required energy references. Moreover, it is discussed how to combine practical considerations, for instance, how to expand the life time of the devices via decreasing the peak values of surge or inrush currents, into the formulation of the model predictive control optimization trouble. It is also presented many simulation state studies which clarify the efficiency and applicability of the suggested supervisory predictive control construction [10].

1.2Aim of the Thesis

War areas suffer from lacking of all the elements of life because of conflicts, so they are dangerous places to live and people escape to save their lives and are forced to live in camps that do not have a lot of services, including electricity.

Because of the war which is occuring in Suriye, many camps were established inside of Syria and outside and due to Turkey's proximity to Syria, Turkey had the largest share in the establishment of refugee camps. In this thesis, it is assumed that there is a refugee camp near the Syrian-Turkish border inside the Syrian territory in the area of Drakush which the Assi river passes through it, in Idlib province, and this river passes through Turkey, and it flows into the sea and will be used its water flow in our thesis to generate hydroelectric power.

The proposed refugee camp contains four blocks and each block includes 25 tents and initial services room which contains refrigerator, washing machine, iron and so on, in addition to a small hospital of camp and water tank which is filled by pump from a near well.

The total energy, which is needed by the camp, is estimated between 100 kW and 110 kW. Each tent is equipped with about 500 watts and initial services room with about 6250W. The maximum power, which is needed by the small hospital, is about 15kW and the maximum power of pump is 10 kW.

The aim of this thesis is design a monitoring and control system of energy for the proposed refugee camp. The designed control and monitoring system works to exploit the clean and sustainable energy sources in the region of project at the time of their existence for supplying the refugee camp with the necessary power, especially that the traditional energy sources is difficult to get them in war places and times.

The main and basic power source, which can be used in our thesis, is the hydro power source which uses the flow of Assi river for generating the electricity. This source is considered the permanent source day and night, especially after inventing technics for producing the electricity from water flow of rivers without need to build dams which need a big effort and have negative effects on the environment and community, but the main disadvantage of this source is a change of abundance of river water flow during the year and from season to other. For that, the generated power from this source is not sometimes enough, so we need to support this source with other clean and sustainable sources like solar energy which is considered a clean and nature source for producing the power. This source has been widespread in recent years, but the main disadvantage of this source that is not always available. For example, if the sun is shining, the power is existent and so that. For that and for a more stable system, our system had to be supported by a third source of energy. This source is the wind power that is available when the wind blows. The best utilization of all these sources with other electrical and electronic components like converters, inverters, batteries for storing the extra energy and generator which can be used in emergency states, needs a control system which works for monitoring, controlling, supervision and distribution of power, so that much of the produced energy is not wasted. Figure1.1 illustrates the suggested general system.

The SCADA system with its components will be achieved for going run the control system and performing the requird tasks and arriving to the objective from this thesis.

The control operation contains the following main prospects with taking in a consideration that the loads is changeable :

1- If the all generated power sources are just enough for feeding the loads, the produced energy is just used for feeding the loads.
2- If the generated power is more than the required power from loads, we have two prospects:
    A. If the batteries are not charged, it is used a part of the produced power for feeding the loads and the excess power will be used for charging the batteries.
    B. If the batteries are charged, it is used a part of the produced power for feeding the loads and the excess power will be used for running heaters or in other useful works.
3- If the generated power is less than the required power from loads:
    A. If the generated power =0:
        I. If the voltage of batteries are equal or more than 11.5V, the loads are fed from batteries.

II. If the voltage of batteries are less than 11.5V, the loads are fed from generator.

B. If the generated power is more than 0:

I. If the batteries are charged and their voltage is more than 11.5V, the batteries will are being charged from power sources and at the same time the loads are fed from batteries.

II. If the batteries are not charged and their voltage is less than 11.5V, the batteries will are being charged from power sources and at the same time the loads are fed from generator.

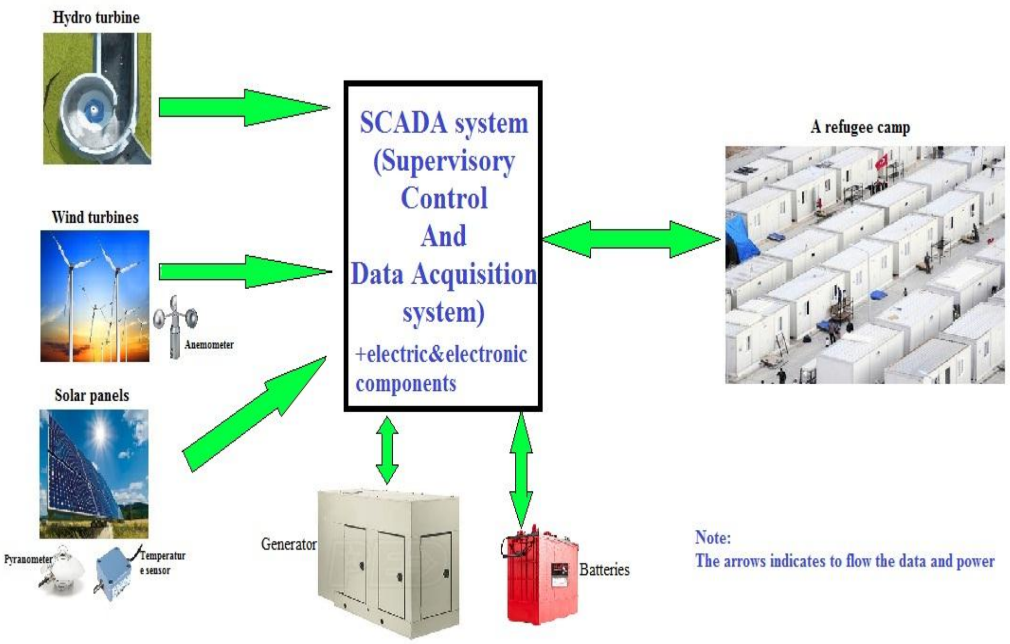


Figure 1.1 The suggested general system

1.3 General Outline of the Thesis

This thesis is organized into seven chapters:

Chapter 1: This chapter includes a literature review, introduction about the thesis and the general idea of our thesis and the organization of the thesis.

Chapter 2: This chapter explains about sustainable energy sources and types of them.

Chapter 3: This chapter explains about the general components of the studied system.

Chapter 4: This chapter offers a background of SCADA systems.

Chapter 5: In this section, we illustrate the types of controllers which can be used with the crossbred sustainable systems..

Chapter 6: In this section, we introduce the practical steps for implementation a suggested SCADA system.

Chapter 7: In this section, we will try to choose and expect a good values of the power sources and some other electric and electronic components that are connected with these components by utilizing a program which deals with the clean energies.

Chapter 8: This chapter contains the implementation of the system and test the effectiveness of it.

Chapter 9: This chapter contains conclusion and future works.

CHAPTER 2

ENERGY AND ELECTRICITY

2.1 Introduction

Electricity is a sort of energy sources. Although it is not a sort of stored energy in fossil and nuclear fuels, it can be acquired from transformation of the chemical energy which is existed in fossil fuel or nuclear energy which is existed in certain metals. It can also be acquired by transformation mechanical energy in the shape of wind to electrical power. In reality, the electrical generators can just transform the mechanical energy to electricity, but at the same time the mechanical energy can generate from some other types of energy, because the energy cannot be created; it can only be transformed from form to the other. In oil, coal power plants and gas the chemical energy of fossil fuel is first transformed to mechanical energy and then mechanical energy is transformed to electrical energy. In the same way, in nuclear power plants, atomic energy is first transformed to heat after that to mechanical energy through steam turbines and finally to electrical power. In hydraulic turbines the mechanical energy from the flowing water, and in wind turbines the mechanical energy from wind is converted to electrical energy. A immediate transformation of light/ heat from sun to electrical energy occurs in solar cells. Solar panels consist of a big number of solar cells which are collected with each other. The heat which is generated from the sun can be collected also by solar collectors, which consist of tubes that sucks temperature from sunshine and heat up liquid which is water in general.

Geothermal energy is also one of the energy origins without harmful effects which are produced from greenhouse and without nuclear rubbish. As you know, both fossil fuel and nuclear power plants have dregs, which have harmful effects on enviroment .On the other way, it is a polluter for the climate. Wind, sun, water and some other clean origins of energy are those without any hurtful effects. There are two main causes for focusing on clean energies. The first one is global warming and pollution, and the second one is that the fossil fuels is lately starting to run out, and the world will stay without coal, gas, and oil. For nuclear energy, it has the same problem due to the bounded reserves of nuclear fuels. The present and future breeds of mankind need to sense that species can only pull out if we live in agreement with nature. We should cancel any waste, and in the end, we must get all our energy from the clean sources [12].

2.2 Need for Energy

Electricity is very important part of the energy that human needs.Every thing in our live depends on electricity like transportation, buildings, and so forth; for that we can not dispence with electricity. The necessity for energy is a reality which we live in and it is a constant fact. This truth generates due to the increase in the population growth and because of transformation to modern living all of the world. When we think well, we can assume that the population growth is stable, as a result every body will have a comfortable and modern life. If the world population stayed constant, we could imagine that one day all the people could have a moderate modern life, if we would act wisely. The miserable reality is that the population is increasing, and there are the bad behaviors by many from individual, nations and countries. Depending on the report which is prepared by British Petroleum in 2011, the world's primary energy consumption increased by 5.6% in 2010, the highest increase since 1973. This ratio is for all energy consumption, which means electricity, transportation, heating and cooling and so on. For example, the electrical power has a highest speed of growth. “Electricity need is increasing at double as fast as total energy use and will increase by 76% by 2030 (as of 2010).” Figure 2.1 illustrates the increase rate of electricity during 2000 to 2012 interval. Although clean energy (mainly the number of installed wind turbines and solar panels) has grown significantly in many industrialized countries, clean energy covers only a fraction of total electricity demand (less than 2% in the world, 2.3% in the United States). Since 2011, China ranks first in terms of installed wind turbines every year, after that comes the United States. However, many areas have more wind power and solar capacity. For example, China estimates between 700 and 1200 gigawatts (Gigawatt is a unit for measuring the electrical energy. Giga denotes one billion. If you look at any electrical device, a simple one, like a lamp, it will be writed the amount of energy (e.g., 100 watts and 60 watts)) [12].

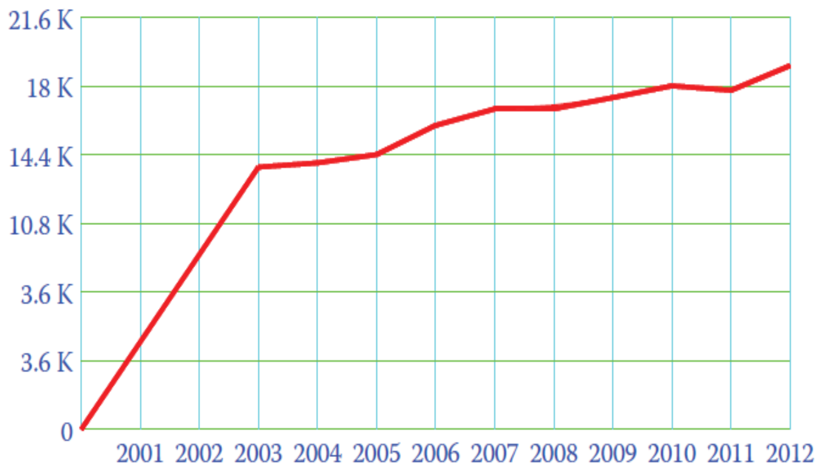


Figure 2.1 World electricity consumption (billion kWh).

2.3 Sustainable Power Sources (Clean and Green)

There are five sorts of green power which can get them from the natural operations, for example, light of sun, winds or water that are the most continuous shapes of energy [11].

2.3.1 Solar Energy

The light of sun is a clean source, and its most immediate usage is fulfilled by receiving the sunlight. The power and radiation from sun can be transformed into electricity for works and industries and into temperature such as hot water by the new technologies.

The solar cells form the Photovoltaic (PV) systems which are used for transforming the light of sun to electricity. In addition the buildings can be heated by using the hot water which are circulating through flate-plate solar collectors. This system is called Solar hot water systems. Finally, if the designs of buildings are good and deliberate, it can be benefited from the light of sun as a source for cooling and heating [11].

2.3.2 Wind Energy

The difference between cooling and heating in the air creates the winds which can be counted as a form of energy which is generated by sun. The wind turbines can exploit the wind flux for transforming it to electricity. Today in farms, the water are pumped by using windmills like a small scale from using the wind energy.

The systems which are exploiting the wind for generating the power are existed for facing the clean energy needs of many institutions. For completeing an existed electric equipping the wind turbines can be employed for creating the electric power. After the wind blows, the system produces the electric energy which flows to compensate the necessity for utilizing given electrical power.

The electrical power can be produced by wind fields. This electric power can be sold by the wholesale energy mart, by two ways the first one is a competitive tender procedures or depending on nodal commitment [11].

2.3.3 Geothermal Energy: Power from the Earth

The heat of the earth generates the energy which is called Geothermal energy. This power can be generated from heated rocks or from the hot water which is existed at depths of ground.

These heat sources are exploited by Geothermal power systems for generating electricity. In smaller level, a nearby building from a geothermal heat pump system can be to aid for coolling it in hot seasons or for heating it in cold seasons [11].

2.3.4 Waterwheels Energy

Hydropower is an old way which was used to generate energy like the waterwheels which were utilized for operating the grinderies and saw-mill which are now widely offered in historic locations in addition to museums.

Perhaps the popular sort of hydropower is produced via a system which depends on dikes that are built to collect water in a dam. When this water be released, the fluxes of water through turbines generate electric power, but in these days, the kineticpower which is generated from flowing water of rivers is exploited via featured technics and transformed into hydropower.

There are two types of hydropower. The first one is called “pumped-storage hydropower” and the second one is called “run-of-river hydropower”.

Immediate utility of hydroelectric energy depends on geographic place. Micro-hydropower stations can be established for producing the electric power to farms and villages, if there are a attainable and obtainable water resources like a river .

The sparingly sized hydropower plants can be established on the minicipal watercourses in the small towns for supplying the electric power [11].

2.3.5 Ocean Energy

The thermal energy which is generated from the heat of sun and the mechanical energy which is generated from the motion of waves and tides are one of the shapes the ocean energy. Ocean thermal power which can be also transformed into electric power by utilization different ways which use temperatures of hot surface water. "Ocean mechanical energy" uses the flows tides in addition to ebbs tides which are occured as a result of the moon gravitational influence and the earth rotation. Power which is generated by waves can also be utilized and transformed for aidding the decrease of one's electric power expenses.

Ocean energy is a developing source of ersatz energy, and the surface of our planet is covered by ocean with more than 70 percent. For that the future of this energy looks favourable [11].

2.3.6 Other Alternative Energy Sources

Bioenergy is a kind of clean power which is generated by biomass for producing electric power and heat or for generating fluid fuels like ethanol and biodiesel which are utilized in conveyance.

The organic materials which come from animals or flora systems represent the Biomass power. Although bioenergy produces the same amount of carbon dioxide which is produced by fossil fuels, but the planted plants for producing the biomass power clear the produced CO_2. In this way, the ecological effect will keep balanced.

Works or institutions that convey merchandises or humans can transform their vehicles to fleets which utilize biofuels like biodiesel or ethanol.

Places which are prepared for burning the biomass that immediately generate a vapour which is catched via a turbine which produces the electric power.

This type of operations have two aims via feeding the place in addition to heating this place. For instance, factories of paper can utilize the waste of wood for generating electric power and heating by vapour. Farms processes can transform waste of cattle into electricity via small floras. Villages can use the produced methane gas via the organic rubbish which uses the anaerobic digestion inside of landfills and utilize it like a fuel for producing electric power [11].

Hydrogen power is with low pollution and high power: Hydrogen element is the most plentiful element in the nature and simplest, until now it is not available as a shape of gas on the suface of earth, but inside of a organic synthesises water and (hydrocarbons like propane, natural gas, methanol and gasoline).

The burning of hydrogen generates a high energy without pollution or with a little. From the 1950s, the space shuttles and other rockets have been using liquid hydrogen for launching. The chemical power which is existed in the hydrogen are transformed into electric power by fuel cells of hydrogen.

Nonetheless, marketing of fuel cells will probably be bounded as an efficient resource of clean power till expenses descend in addition to improvement of the toughness. The hydrogen is utilized in industrial processes for iterating petroleum, creating fertilizer, processing metals and treating foods. Not only that but also, hydrogen and oxygen atoms are consolidated to produce electricity by using hydrogen fuel cells.

The other applications of this kind of the clean power comprise of huge cells of fuel that supply contingency electric power for constructions and far places and electrical motor automobiles and marines ships which is feed by cells of hydrogen fuel [11].

2.4 Microgrid

The microgrid can be defined as a small-scale energy grid which can run autonomously or cooperatively with other small energy grids. The exercise of using microgrids is known as district, decentralized, dispersed, distributed or embedded energy generation.

Any small-scale, localized energy station that has its own production and storage sources and definable limits can be rated a microgrid. If the microgrid can be integrated with the area's main energy grid, it is often indicated to as a hybrid microgrid.

Microgrids are typically supported by generators or clean wind and solar power sources and are often used to supply backup energy or supplement the central energy grid through periods of heavy demand. A microgrid strategy that integrates local wind or solar sources can supply redundancy for essential services and make the main grid less susceptible to localized disaster [13].

The moicrogrids are sorted to four major classes according to a group of criteria which are characterized them.

The standards which are very significant: (1) the tying of microgrid to a bigger grid, (2) the dispatchable generation kind. The third significant difference is the apportionment kind and size inside of the microgrid, but apportionment introduces many alternates, that may convert it harsh to admit specifying limits. The size of microgrid can be also a basic standard, but it is available many ways to specify the size and this standard is a continuous series. For distinguishing among various size groups, there are other requests may be a very clear method. Eventually, it is available various types of controls which are undoubtly a probable difference. Switchgear is used for disconnecting in addition to connecting with a bigger grid which is included in the first standard. Controls also take in a consideration the work with generators which is defined via another standard. The rest of the controls interest mostly with load management which is an essential matter, nonetheless the categorization of this issue is difficult because numerous choices are available. The four primary microgrid kinds result from intersection of grid connectivity (close or far) and size (small or big), in spite of the second kind most likely needs more categorization [14].

2.4.1 Types of Microgrids

There are many types of microgrids for different applications: Whether your goal is to bring capacity to a remote control location or improve energy and reliability security, there exists a microgrid that meets your preferences. Microgrid categories are organized by their connection setting to the primary grid (off-grid or grid-connected) and their kind of ownership (facility or community). Categorizing microgrids is important because it permits standardized designs that allow the creation of repeatable, modular, and scalable systems. Here is a glance at four of the groups:

Off-grid facility microgrids are the most typical type of microgrid globally. They are normally implemented in remote locations that don’t get access to the traditional grid, such as remote military bases or isolated structures like resorts. They’re in a position to minimize fossil gas dependence while maximizing clean energy make use of.

Off-grid community microgrids, such as for example those that are located on islands or in remote control communities , serve multiple producers and consumers in places where the main grid is not accessible. Like off-grid service microgrids, they integrate a higher percentage of clean energy, but community microgrids differ because they are focused on providing energy gain access to for a community to make sure its critical services are available.

Grid-connected facility microgrids provide increased energy reliability to main-grid linked sites like business campuses and hospitals already. The greatest benefits will be the potential for cost benefits, resilient and secure energy, and increased use of clean resources.

Grid-connected community microgrids are designed to share energy usage within a grouped community, such as multiple consumers or small municipalities even. The cost is reduced by them of energy and provide more reliable energy from clean sources. Grid-connected microgrids may also be designed with the capability to disconnect from the primary grid (islanding) and manage all or part of its distributed energy resources.

A number of business models can be found to finance these microgrids. These choices include customer-owned, microgrid-as-a-assistance, and pay-as-you-go business models.

Customer-owned and microgrid-as-a-service (MaaS) business models yield similar returns. The principal difference is certainly that in a customer-owned business design, the financial risk falls onto the clients. Compared, the MaaS model offers a flexible ownership framework that allows customers, electrical utilities , and other financing partners to collaborate and capitalize on market opportunities strategically.

The small-scale pay-as-you-go microgrid model is perfect for the developing world. Although in first stages still, this flexible payment system could significantly expand power options and electricity availability for consumers with low or variable incomeavailability for customers with low or adjustable income.By categorizing business and microgrids models, the energy industry can meet an integral objective of minimizing microgrid program costs, such as areas such as for example project development, system style, and support [15].

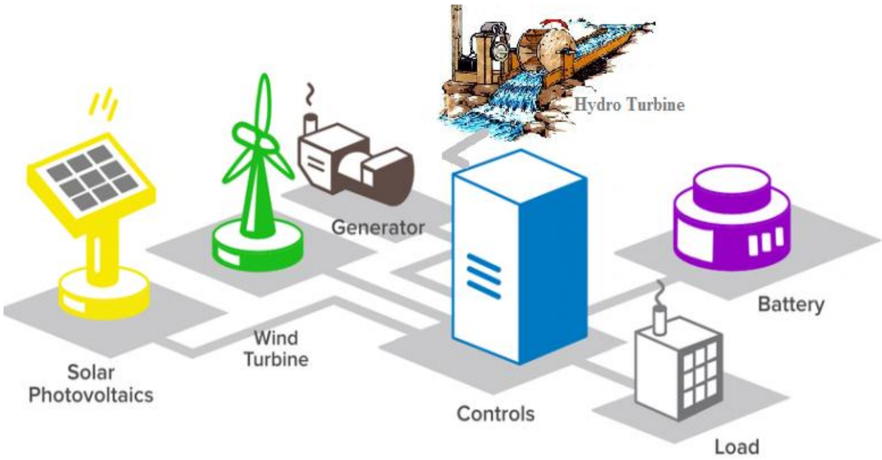


Figure 2.2 Off-grid microgrids

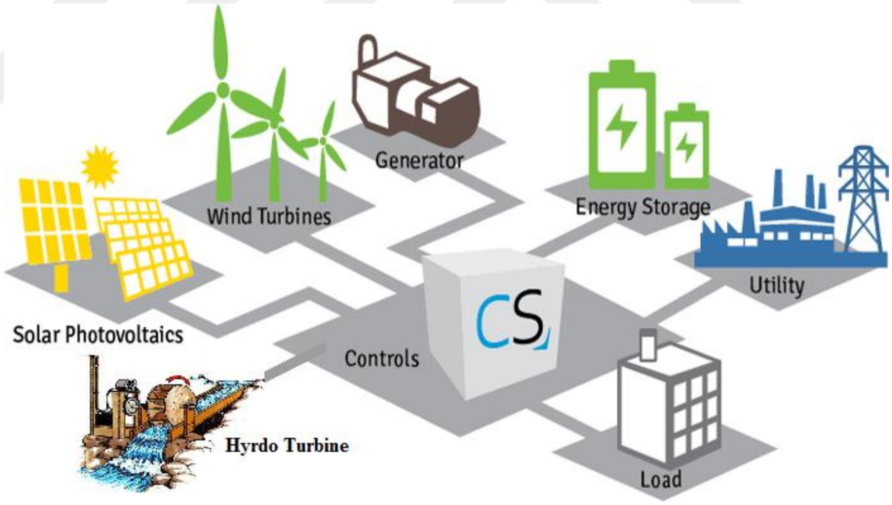


Figure 2.3 On-grid microgrids

CHAPTER 3

THE GENERAL COMPONENTS OF THE STUDIED SYSTEM

3.1 Hydro Power

3.1.1 Introduction

Hydroelectric energy is a shape of clean power source. Hydroelectric energy stations generate electricity without utilizing energy sources which pollute the water, land or air as other energy stations. Hydroelectric energy is result from streaming water winter and runoff from mountain streams and pure lakelets in spring. Falling the water by the force of gravity can be utilized to turn turbines and generators, which conduct to generate electricity. Hydropower is considered the largest clean source which is utilized for generating the electricity. It takes an important role in several places of the world whereas more than 150 countries producing hydroelectric energy. In 1997, the International Journal made a survey on Dams and Hydropower whereas found that hydropower provides fully 90% of national electricity generation in 23 countries and 50% in 63 countries. There are ten countries which acquire basically all their mercantile electricity from hydro, encompassing Paraguay and Bhutan, several African nations, Norway [16].

There is approximately 700 GW of hydro capacity in procedure worldwide, producing 2600 TWh/year (regarding 19% of the world's electricity creation). About half of the capacity and era is in European countries and North America with Europe the biggest at 32% of total hydro use and the United States at 23% of the full total. Even though, this rate is decreasing as Latin and Asia America commission huge amounts of new hydro capacity mini, micro and small hydro stations thought as plants significantly less than 10 MW (usually, 2 MW and 100 kW, sequentially) also take a key role in lots of countries for rural electrification. Around 300 million people in China, for instance, based on little hydro [16].

3.1.2 Historical Background

The wooden waterwheel was the beginning of Hydropower. Several kinds of Waterwheels had been in usage in various places of Europe and Asia mostly in Mesopotamia that are in usage untill now on Euphrates River for milling grain and irrigation for a few 2,000 years (see Figure 3.1) [16].

When the industrial revolution occured, waterwheel technology had been improved to an excellent art and efficiencies approaching 70% were being performed in the several tens of thousands of waterwheels which were in regular usage. In the 19th century, engineering skills developed and combined with the need for producing electricity by higher speed and smaller instruments, all that conduct to the improvement of modern day turbines. Supposedly the first hydroturbine was patterned in France in the 1820s by Benoiˆt Fourneyron who gave a name which is a hydraulic motor to his innovation. When that century began to finish, several mills were being subtituted their waterwheels with turbines and governments were starting to concentrate on taking advantage of hydropower for large-scale equiping of electricity.

Figure 3.1 Waterwheel

The first half of the 20th century was the golden era of hydropower, before oil became as the predominant strength in power supply. North America and Europe stablished hydropower plants and dams at a fast average, taking advantage of 50% of the technically existed possibilities. Hundreds of instruments providers sprung up to provide this booming market. Whereas the big hydro industrialists have maintained their work on export markets, specially to advancing countries. Since the 1960's, the small hydro manufacture has been on the descent. Some countries (especially Germany) have supported this department in new years with charming politics favouring 'green' electricity generation, but small hydro cannot generally rival with existent nuclear or fossil fuel energy plants so that, without environmental rewards to utilize non-polluting energy resources, there has been no strong mart for small hydropower in advanced countries for several years [16].

The first hydroelectric energy station was stablished in Cragside, Rothbury, England in 1870. Manufacturing usage of hydropower began in 1880 in Grand Rapids, Michigan when a dynamo driven by a water turbine was utilized to light theatre and storefront. In 1881, at Niagara Falls in New York, a brush dynamo was tied to a turbine in a flour mill to supply street illumination. Early hydropower stations were much more efficient and reliable than the fossil fuel-fired stations of the day. This conducted in a increase of small- to- medium sized hydropower plants which were distributed in places which contained a need for electricity and a sufficient amount of flowing water. After electricity request increased, the size and number of hydropower, fossil fuel and nuclear stations rose. At the same time, worries emerged around social and environmental effects. Today, hydropower stations spread on a huge distances, from a some watts to many GW. There are always specific sites for hydropower projects which are designed depending on the river system which are established on it. Figure 3.2 illustrates historical regional hydropower production between 1965 and 2009 [16].

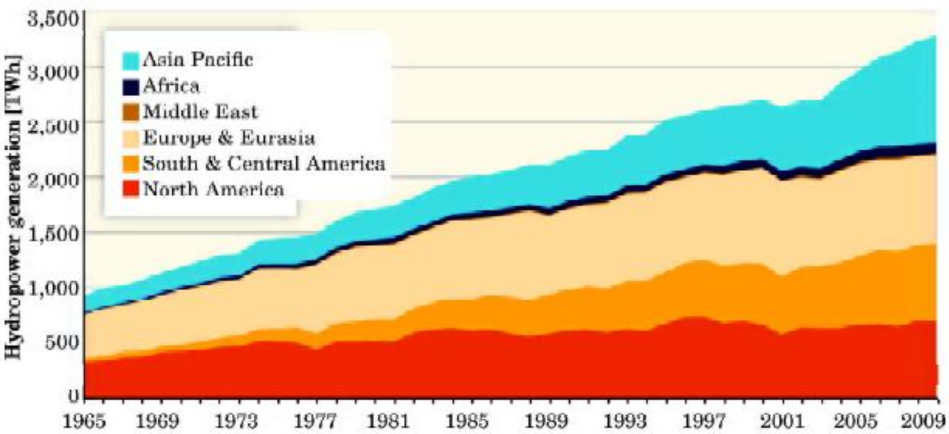


Figure 3.2 Hydro power generation by region

3.1.3 Hydroelectrical Systems

Most hydroelectric energy is produced by dams which are established on the big-stream rivers, that conduct to create a reservoir behind the dam. The potential energy is stored by making the level of the water behind the dam is higher than the level of water which is below the dam. When water streams down across the penstock of the dam which is driving the turbines which generate the electricity by transforming some of potential energy which is stored in the water.

Table 3.1 Classification of hydro power plants according to installed capacity

Hydro Category	Power Range
Large /Very Large	>100 MW/ 0.5 GW
Medium	25 - 100 MW
Small	1 - 25 MW
Mini	100kW - 1 MW
Micro	5 - 100 kW
Pico	< 5 kW

Hydroelectric energy, such as other alternative resources, is clean and comparatively inexpensive over the long period even with maintenance prices and initial building, because the dam minimizes the river’s normal stream average, residues which are usually carried downstream by the water are instead deposited in the reservoir. Finally, the residue can close the penstocks and the dam becomes useless for energy production. Big-scale dams can have a large effect on the regional milieu. When the river is firstly closed, farmlands are often flooded and whole populations of people and wildlife are displaced by the rising waters behind the dam. In some status, the reservoir can flood hundreds or thousands of square kilometres. The reduced flow downstream from the dam can also negatively effect human and wildlife inhabitances living downstream. Also, the dam can prevent the fish from travelling upstream for reproduction. Not only that but also hydrous creatures are frequently killed in the out-take pipes and the penstock because they are caught there. The local climate can mutate because of the big quantity of evaporation occurring, because the surface area of the reservoir is large. Recently, electric generators are run by modern hydro-power systems which are utilized most of them for this aim. The whole hydroelectric system contains the pipe (penstock), fine control of the generator, flow control, the electric generator, the turbine and wiring for electricity distribution. The dam guarantees a stable feeding of water to the system without swings and gives possibility of power storage in the reservoir. It may also be utilized for objectives other than producing electricity, e.g., for water supply or roads. Small run-of-the-river systems from a moderately large and stable flow may demand only a retaining wall of low level, i.e., enough to hold the penstock fully submerged [16].

3.1.4 Damless Hydropower Systems

A damless hydro power station is a new resource of electricity which has been being well improved and explored for working to make this technology more cost-efficient. All of various models ,which are being established, have two things in common: the raise of the efficiency and the reduction of the costs. The decrease of the ecological damage is one of the main advantages of utilization this new source of electricity [18].

More than a century ago, in 1882, the first time that is permitted to generate electricity by moving water on the Fox River in Wisconsin, hydropower has always had an important role in the propagation of the electricity among the world people whereas hydropower stays as one of the most worthy clean and sustainable power sources and they are considered a non-radioactive, a non-consumptive, and a non-polluting utilization of water sources.

In the last couple of decades, a hydropower dams size is a main talk subject which have been occuring. In spite of that the hydropower has many advantages, it also has some disadvantages, mostly in what relates with the ecological impacts and social vagrancy that it can cause. For that, a lot of researchers are working to find new methods to generate hydro power without impacting on the milieu [18].

The damless hydro power stations are starting to spread widly all over the world, mostly in in mountainous regions, rural and remote places inside of developing countries. A run-of-river is an other name of damless hydro power stations. Although the countries which are considered the largest in producing the electricity from the hydroelectric power projects, they have been also establishing run-of-river stations. These countries encompass Brazil, Canada and China. Even though, there are also countries that are utilizing the new damless hydro power stations because of their natural geography. These encompass Nepal, Austria, Norway and Switzerland [17].

A. Damless hydro power plants advantages:

1. A cleaner energy and fewer greenhouse impacts just such as the most conventional and huge energy stations, damless hydro energy stations also exploit the water's power. Although, one of the things which are basically various between these two types is that the run-of-river stations don't require any water reservoirs. For that, this permits the removal of methane and the carbon monoxide emissions that are resulted by the disintegration of organic matter in the water reservoir and that normally happen on the traditional hydroelectric stations.
2. There isn't need to reservoirs and the flooding is less: One of the basic matters that have been debated about conventional hydroelectric stations is the truth that they normally have a passive effect on inhabitances who live next or near the river, naturalistic habitats, and even the inclination to devastate all the farms in the region. Nonetheless, run-of-river systems don't need either a water reservior as well as they don't also require a big flooding of the upper side of the river. For that, these indicates that the mentioned negative impacts don't happen when there is the construction of these smaller scale stations.
3. The premier costs are often less than the costs that are required for building a huge hydroelectric dam. In addition to it is also a lot more elastic since it can be executed in almost any creek, stream, or river when it has the suitable height. Because of run-of-river systems are normally a lot smaller, they don't require a lot of pieces of land next the river itself. In some states, they don't also require any piece of land.

B. Damless hydro power plants disadvantages:

1. Generated energy is unpredictable. That is one of the largest troubles of damless energy whereas power storage is minimum or nonexistent at all. For that, this approach just can't be suitable to the request. The fact is that it will be capable to generate a lot more power when the stream of the water source is higher through raining months, while they can even stop generating power when the stream is too low through dryer months or summer. İf the damless plants are established in regions where the water source get frozen, it can also be a worry source chiefly during winter months. This will also prohibit power to be generated.
2. Availability of suitable sites is an important factor to construct a success system. In addition to the success of the location encompasses two significant factors which are the head and the stream of water. For that, this factor can largely raise the costs, it's better to search for locations where there is a strong ramp in the river and these types of locations are a very hard to find.

There are important researches in this field to beat these drawbacks. New technologies have been improved. New types of turbines that can run in lower water ramp have also been improved. In such a scenario we can say that damless hydro energy stations is really a good way for the generation of electricity.

3.1.5 New Damless Technics

There are alot of technics that can be used for generating the hydro power without dams like

Hydrokinetic, a run-of-river or water vortex power plant which can be such as a micro hydro power station which can generate the power by utilizing a water flow or a flowing steam and the produced energy from this system can be used for feeding isolated communities or houses and is sometimes used in off-grid systems [19-20].

Gravitational water vortex energy station is a clean technic which produces electricity from sustainable and clean power resource. In the vortex energy station, water is entered into a circular trough tangentially which generates a free whirlpool and power is extracted from the free whirlpool by utilization a turbine. The major features of this kind of energy station is ecological friendly and the electricity is produced from ultralow hydraulic pressure. Because of the hydraulic head demand is as low as 1m, this kind of energy station can be set up at a stream or a river to produce electricity for few homes [21].

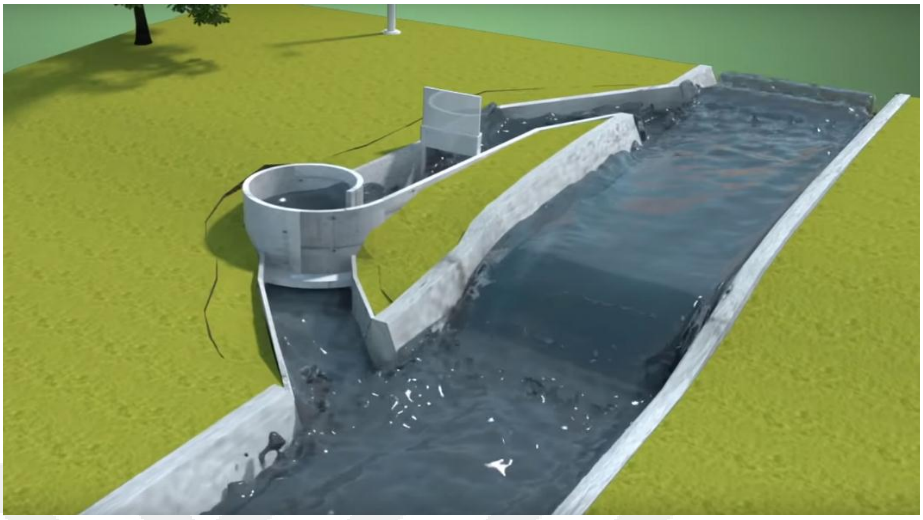


Figure 3.3 One of gravitational water vortex power station

For example, the Belgian company Turbulent which is one of firm which works in damless hydropower stations. In 2017, the company built its first 15 kW low head hydropower turbine which could be set up into any river with a small height variance (i.e. a downhill or a waterfall running river). The turbine has a complete stream of 1.8 m^3/s with a given height variance of 1.7 m. Through the test stage, it is generated a beneficial power output about 15 kW at an qualification of 50%. This power is sufficient to feed about 60 homes in Chile given a rate domestic energy requirement of 0.25 kW [22].

The main components of this system, which is suggested by Turbulent company, are [23]:

1. Generator: Excellent efficiency IE3 Generator and Gearbox by Flender-Siemens, designed for 24/7 running.
2. Fish-Friendly Vortex: The unique trough form converts the arriving stream into a low-pressure whirlpool, permitting aquatic life to exceed the turbine without harm.
3. Rotor**:** It has tilting blades manually-controlled to generate the most power in both winter and summer stream.

4. Trash Rack: Protective trash rack for big debris. Small debris can safely pass, minimizing the danger of blockage.
5. Sluice Gate: Automated sluice gate to control stream.

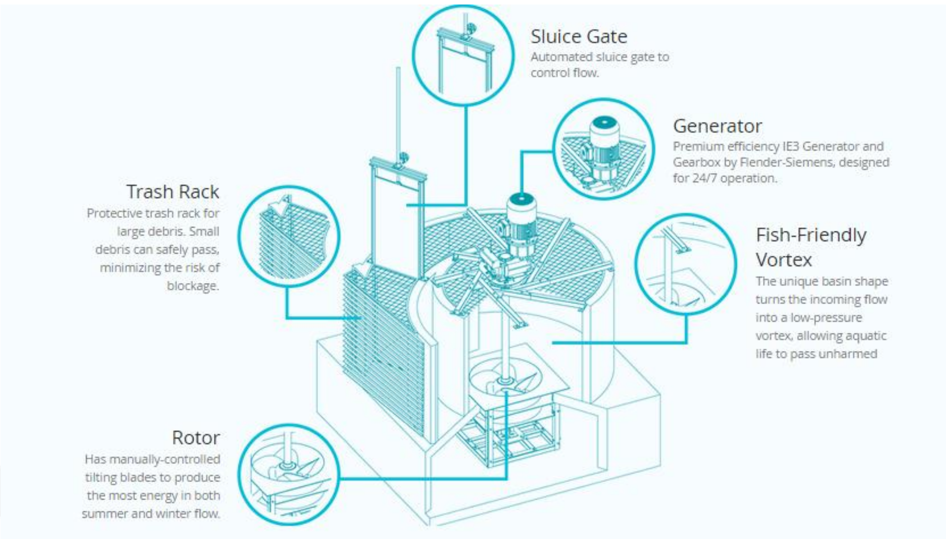


Figure 3.4 The main components of gravitational water vortex power station system- Turbulent (as an example)

3.2 Solar Power

3.2.1 Photovoltaic Cell

Photovoltaic (PV) are solid-state, semi-conductor kind elements that generate electricity when recieve the light. The word photovoltaic actually means "Electricity from light." For example, most of the hand-held calculators run on the solar energy when the light comes from room lamp. Another larger technical systems also depends on this technology [24].

Photovoltaic are the immediate transformation of light into electricity at the atomic range. There are some materials that have a characteristic which is called the photoelectric impact which makes them to suck photons of light and give electrons. After capturing these free electrons, the electric current is generated and utilized as electricity. In 1839, it was the first time where a French physicist, Edmund Becquerel noted the photoelectric impact and found that specific materials would generate small quantity of electric current when they are exposed to light. The nature of light and the photoelectric impact, which photovoltaic technology is depend on, are defined by Albert Einstein, in 1905, who won a Nobel Prize in physics later. In 1954 Bell Laboratories built the first photovoltaic module. It was called a solar battery and was mostly just a nosiness because it was so expensive and it could not utilize widely. The first serious utilization of the technology was in the 1960s when the space industry began to supply energy aboard spacecraft. By the space works, this technology developed, its reliability was appeared, and its cost started to decrease. When there was a power crisis in the 1970s, photovoltaic technology took confession as an exporter of energy for non-space works.

The process of a basic photovoltaic cell appears in Figure 3.5. Not only that but also it is surnamed a solar cell. Solar cells consist of the same types of semiconductor elements, like silicon which is utilized in the microelectronics manufacture. For solar cells, a thin semiconductor wafer is especially addressed to compose an electric range, negative on one side and positive on the other.

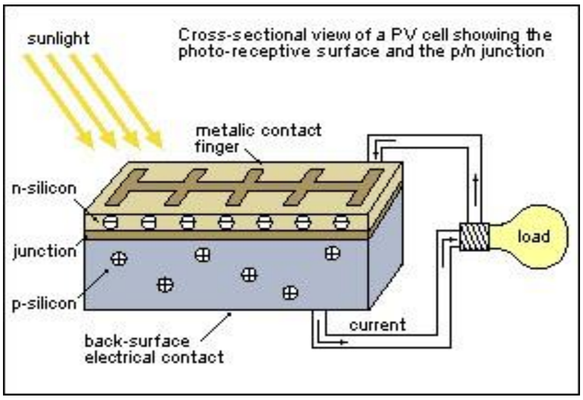


Figure 3.5 Working principle of a PV cell

When light power falls on the solar cell, electrons are separated from the atoms in the semiconductor element. If electrical conductors are attached to the positive and negative sides, forming an electrical circuit, the electrons can be captured in the form of an electric current that is, electricity. After that, the generated electricity can be utilized as a current for feeding the load [24].

3.2.2 Solar Panel

When collection of photovoltaic cells are connected in series and parallel together, the solar panel produces which forms an usable energy source and for understanding the operation which undertake it this solar panel, the study should start from the photovoltaic cell and main nucleus which converts the light to electrical current. By the other words, this study can start from the electrical circuit that describes a cell [24].

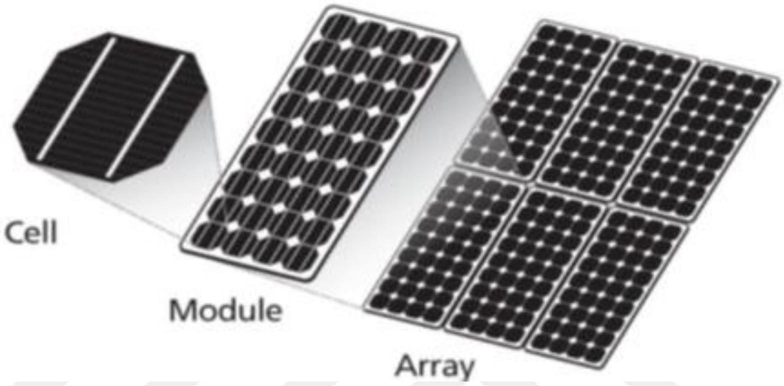


Figure 3.6 Photovoltaic system **[**6,25]

3.2.3 I-V and P-V Curves of Photovoltaic Cells

The relation, which connects the Current with voltage, are used to specify the electrical features of photovoltaic (PV) elements and is represented by using curves. The relationship, which are existed between the current and voltage, is drawn by representing the current against the voltage and it is taken in a consideration the short-circuit current (Isc) through loading and the open circuit voltage (V_{oc}). The curves are drawn to acquire implementation ranges of PV systems (arrays, modules, cells). The curve of I-V is acquired experimentally by highlighting the photovoltaic (PV) cell or module to a specific range of beam of light with keeping a constant cell temperature, changing the load resistance, and taking the measurements of the generated current. The horizontal axis measures the voltage and the vertical axis measures the current. There are two ends of I-V curve the first one is the short-circuit current (I_{sc}) and the second one is the open-circuit voltage (V_{oc}). The definition of short-circuit current (I_{sc}) is the current which passes the solar cell when the voltage of the solar cell is zero (i.e., when the solar cell is short circuited) [30]. Open circuit voltage is the voltage through the negative and positive ends with open circuit circumstances without any flow, by the other words it is similar to the load resistance when it is infinite. IV curves can appear peak power point which is existed on the upper right nook from the head of curve where the rectangular space, which is under the curve, is the biggest [6,25]. There is a large rangeof currents and voltages which photovoltaic cell deals with it. When the load resistance is being changed from zero (short circuit) to infinity (open) the circuit, the efficiency is changed to make the cell gives the maximum power [6,25]. In Figure 3.10 clarify I-V curve which has a collection of important factors that should be studied for installing and maintaining photovoltaic energy systems well. These factors are:

- **Short-circuit current (I_{sc}):** is the highest produced current through a module or cell and is scaled when the cell is shorted whereas the resistance isn't tied. The cell's surface space and the amount of solar radiation which is falling on its surface specifies its worth. This current is measured by units of Amperes and all electrical capacity design calculations uses I_{sc} because it is the maximum produced current via a cell.
- **Maximum power operating current (I_{mp}):** is the highest current which is measured by unit of Amperes and is produced by module or cell. In addition to it is identical with the maximum energy value on the array's curve between current-voltage (I-V).
- **Open-circuit voltage (V_{oc}):** is the highest voltage which is produced by means of the cell. When there isn't any external circuit that is tied to the cell, this voltage is measured.
- **Rated maximum power voltage (V_{mp}):** which is identical with the maximum energy value on the array's curve amongst current-voltage (I-V).
- **Maximum power (P_{mp}):** which is the highest energy value which is produced from a Photovoltaic module or cell and appears on the I-V curve at the maximum power value. If a module runs outside of its maximum power value, the amount of produced energy is decreased and there will be losses in power. Thus, this point is required for any process which uses any PV module.

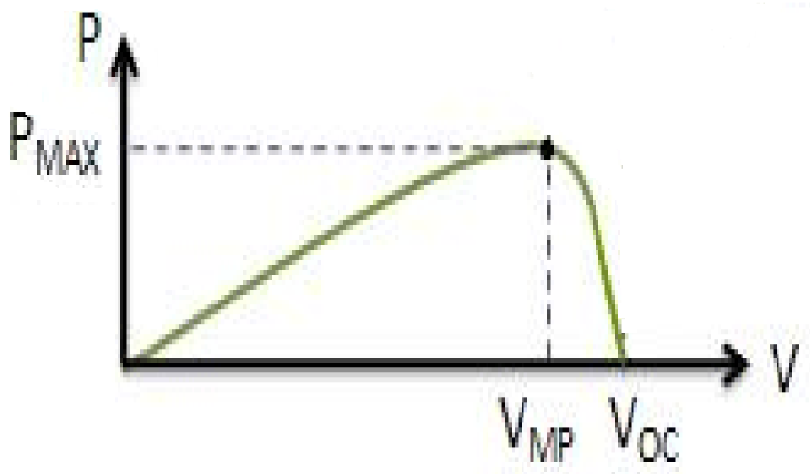


Figure 3.7 Maximum power (P_{mp}) [6,26]

3.2.4 Irradiation Effect

This term illustrates the link which connects the fallen irradiation with the Photovoltaic voltage and current. The fallen irradiation affects on PV output energy whereas the relation that connects the PV module short circuit current (I_{sc}) with the irradiation is linear. On the other hand, the relation that connects the open circuit voltage (V_{oc}) with the fallen irradiation is different whereas icreasing the fallen irradiation conducts to increase the open circuit voltage (V_{oc}) exponentially to the maximum worth, and it changes a little with the light density [6,25].

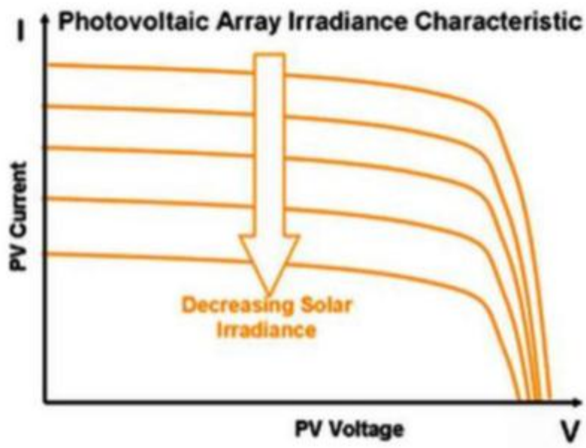


Figure 3.8 Effects of the incident irradiation on module voltage and current [6,25]

3.2.5 Temperature Effect

This idiom represents the link which connects current and voltage of PV with the module temperature. The temperature of weather affects strongly on the module performance whereas short circuit current is slightly affects when the PV module temperature rises more than the Standard Test Condition (STC) temperature, that is 25 °C. Nonetheless, open circuit voltage is extremely affected when the module temperature passes 25 °C. By the other words, the decreasing voltage is proportionally higher than the increasing current. For that, the output energy of the PV module is decreased [6,28].

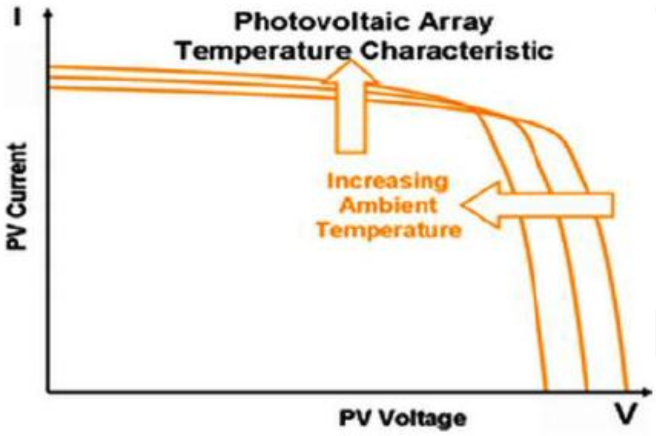


Figure 3.9 Effect of ambient temperature on module voltage and current [6,25]

3.2.6 Maximum Power Point (P_{MPP})

It clarifies the link between the manufacture and module technology. Maximum electrical energy of the Photovoltaic module is the current at maximum power point (I_{mp}) multiplied by the voltage at maximum power point (V_{mp}), that gives the maximum possible power according to Standard Test Condition (STC). Figure 3.10 illustrates the "knee" of the I-V curve which is called the maximum power point (P_{mpp}) of the Photovoltaic module/system. The maximum electrical power is produced at this point [6,29].

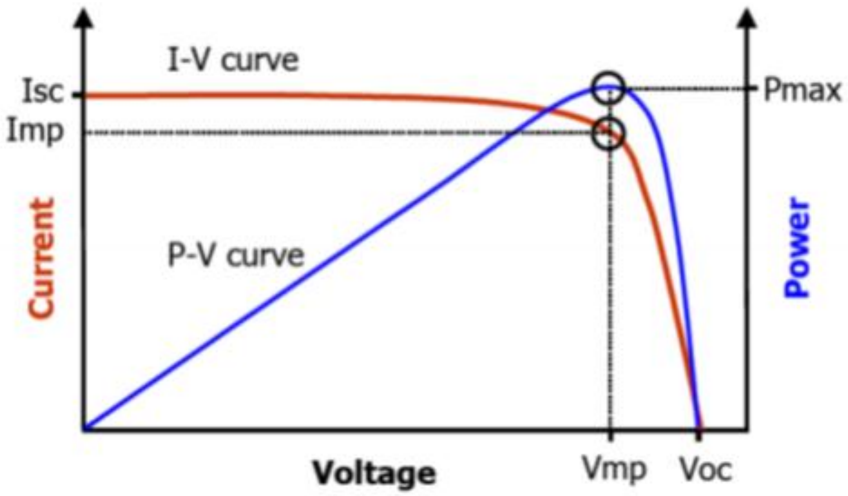


Figure 3.10 Maximum power point (P_{mpp}) [6,26]

3.2.7 Fill Factor (FF)

It is one of the significant factors of Photovoltaic cell/module whereas it expresses the biggest area of the rectangle, that is found in the I-V curve. This significance comes from connecting Fill factor with the magnitude of the output power. When the fill factor is higher, the output power is higher. Figure 3.11 clarifies the fill factor which represents the proportion that results from dividing the two areas of rectangle and the Equation 3.1 illustrats this parameter. The best value of this factor is 1 and this indicates that the two areas of rectangles are identical [6,26].

$$FF = \frac{I_{mp} \times V_{mp}}{I_{sc} \times V_{oc}} \tag{3.1}$$

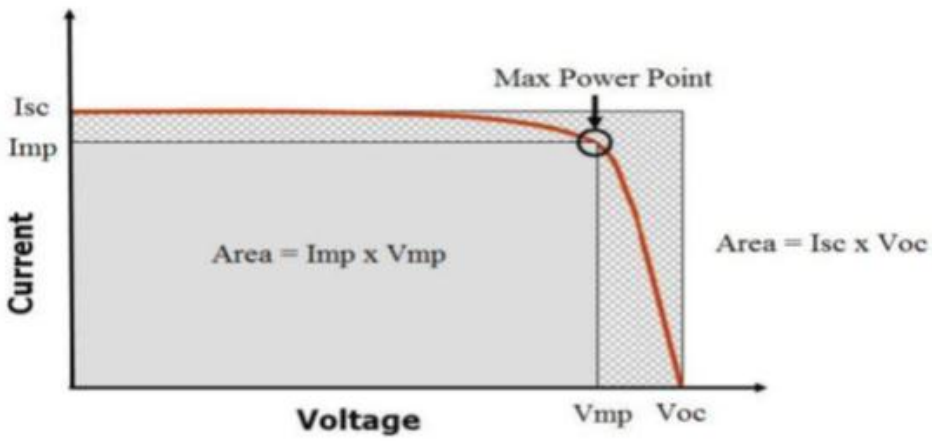


Figure 3.11 Fill Factor [6,26]

3.2.8 Module Efficiency (ηPV):

It is the capability to invert the light of sun to electricity. The need of this efficiency comes from drawbacks which is connected with area of system place like a roof-mounted system. Depending on the math equations, the output power of the module is limited for per unit area. The highest efficiency of the PV module is given by [27].

$$\eta_{PV_{max}} = \frac{V_{mp} \times I_{mp}}{C \times A} \times 100\% \quad \textbf{(3.2)}$$

G is global radiation and considered to be 1000 W/m^2 at (STC).

A is the area of the PV module.

3.3 Wind Power

Wind power has been used for a long time. These days, the use of wind power systems are growing speedly all over the world. The wind technology has been rapidly advancing, this development has made it gainful, but at the same time also complicated. The newest techniques and the aerodynamics has to be firstly studied and understood for developing this system to generate a non-polluting and more efficient power. The hugest wind turbines produce energy up to 8 MW, but comparatively smaller types are more popular. There are a two various types of wind turbines. The norm systems were installed as a fixed-speed turbines in early 1990's. In the last years, when the wind turbines are installed, the changing-speed turbines have become the prevalent kind. These changing-speed wind turbines have several features like decreasing mechanical stress, increasing power capture and improving energy amount. There are some cons like losses in energy electronics and the risen devices cost because of more complicated structures. Figure 3.12 illustrates the components of a horizontal-axis wind turbine [31].

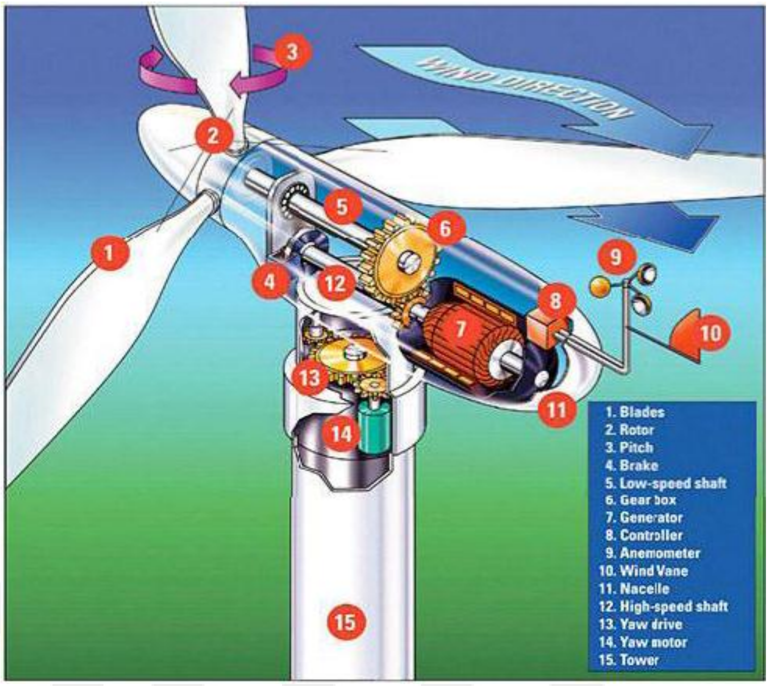


Figure 3.12 Wind turbine structure, with all the different components listed

3.3.1 Different Wind Power Turbines

There are two types of orientation of axises of wind turbines, these are either horizontally or vertically. The horizontal-axis wind turbine is the more popular turbine and it has three blades. Not only that but also there are four various kinds of wind turbine generator technologies (WTG):

- Constant speed WTG.
- Limited changing-speed WTG.
- Changing -speed WTG with double fed induction generator (DFIG).
- Changing -speed WTG with front-end converter system.

These days, the changing speed WTGs are more popular for larger turbines, because of the truth which they are lower voltage fluctuations, have lower mechanical stress and aerodynamically more effective. The changing speed WTG with permanent magnet synchronous generator (PMSG) and front-end converter system can be considered as the most effective WTG these days, because it is lighter and smaller than the one with a DFIG (Double-fed induction generator) and it also does not need slip-rings. In addition to it does not require a gearbox. If a big quantity of wind energy is established in small circumference, the changes of wind can have a large effect on the voltage. The changing-speed WTGs do not supply the system with inertia, because a converter is installed between the grid and the wind turbine. That can be resulted to unstable frequency. The DFIG's may also "crow-bar" within a mistake and can expend big quantity of reactive energy, that can affect on the stabilization of the grid [31].

3.3.2 Wind Power Production

The power of wind is actually generated by the changes of temperature on the surface which are made by the sun. The energy of wind is represented by the Equation 3.3.

$$P = \frac{1}{2}\rho A V^3 \tag{3.3}$$

where ρ is the air density, A is the area the air mass flows through and V is the wind speed.

This formula illustrates that, an raise of 10% in wind speed will give in a 30% raise in the existed energy. Nonetheless, the highest energy that can be acquired from the wind without any energy losses from exploiting the wind is 59%. This is the so called Betz limit, that was found out by Betz in 1926.

In addition there are also two parameters of wind turbines which are called cut-in and cut-out speeds. When the turbine starts to rotate and thus energy starts to be generated, the wind speed is called the cut-in speed. This speed is usually around 4 m/s. When the turbine stops rotating, the wind speed is called the cut-off speed which is a precaution measure for preserving the wind turbine, e.g. when there is a storm. This speed is usually around 25 m/s. Figure 3.13 illustrates the energy curve for a 2 MW wind turbine.

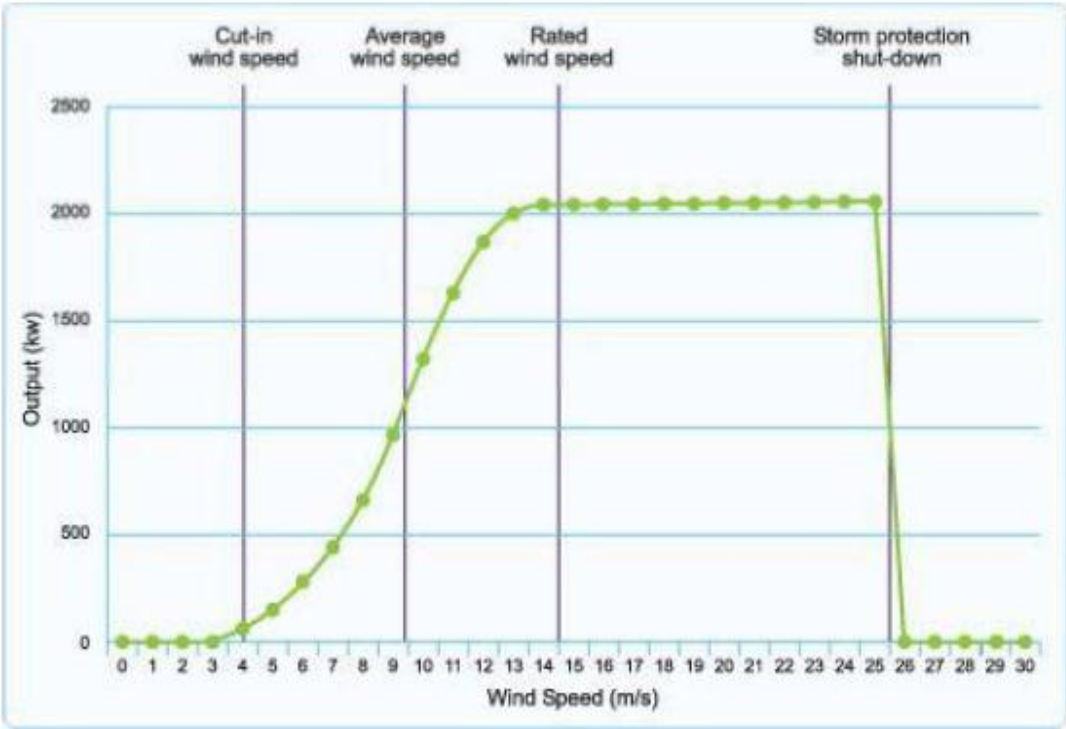


Figure 3.13 Wind power curve in changing wind speed

When the size of the wind turbine is chosen, the increase of size of wind turbines means more effective, but larger doesn't always mean better because the bigger size means a local local lifting equipment with higher possibilities which may be not available. Thus, it is possible to install a bigger quantity of smaller wind turbines which would generate the same quantity of energy and also acquire the wind energy on a more expanded area. Nonetheless, a smaller inertia of smaller wind turbines affects negatively the energy smoothing [31].

3.4 Electrical Components for Power Plant

The power generating units needs many other components for achieving the required task. The most important components are the inverters and converters. In addition other elements are telecommunication components, fuses, automation and cables [31].

3.4.1 Control and Automation System

Control is a good way for the deployment of sustainable power systems. Water, solar, wind and other clean power sources need advanced control techniques for high-reliable and performance process [31]. We will talk about this component detailly in the following chapters because it is the focus of our work in this thesis.

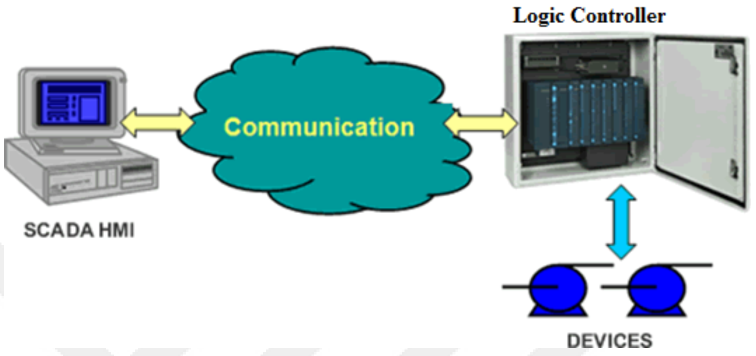


Figure 3.14 The general SCADA control system

3.4.2 Batteries

It is considered a difficult question when it is discussed the cost efficiency of supplying a battery system to the mixed off-grid energy station. In addition the views about the significance of batteries are been different, especially after it has been discussed in various research studies. In spite of raising the cost of battery system in the rate of 40% of the complete energy station through the 20 - 30 years from appearing the concept of mixed systems. However, if enough back-up energy is not existed, the reliability pending peak consuming can be dangerous.

When batteries have less than 80% of the rated capacity left, they are consumed. However, until 50% of the rated kept capacity, the batteries can be utilized whereas it requires to be inform, that the obtainable energy from the battery will be minified. Specially in crossbred systems, when the capacity of battery decreases, the fraction of solar reduces. In addition the aging batteries have a negative effect on safety, because of serious cases of battery failures. It is economically considered that lead-acid batteries is the best selection, when it is wanted to add battery storage system to the energy station, specially for bigger systems, in spite of their age is no long. Not only that but also because of the technical parameters of Lithium-ion batteries, they are considered the best proper option to freelance energy systems. The expensive price of Lithium-ion batteries may economically make it not worthy so far. If the system is designed, it must be taken in a consideration, specially in state of deep discharging protection and frequent full charging, that the use of a larger number of batteries will conduct to long-term savings.

The battery system connection generally illustrates in Figure 3.15. There are two ways to connect the batteries together. The first one is the series connection to get a higher voltage and the second one is the parallel connection to get a larger current [31].

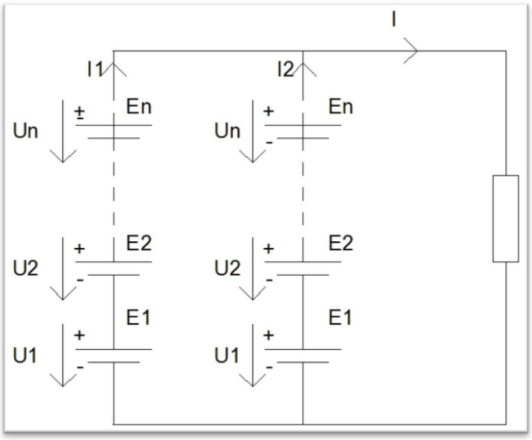


Figure 3.15 Line diagram of a battery storage system

3.4.3 Converter

The power transformation systems can be sorted depending on the kind of the output and input power[32]

- AC to DC (rectifier)
- DC to AC (inverter)
- DC to DC (DC-to-DC converter)
- AC to AC (AC-to-AC converter)

According to classification the previous power conversion systems are explained:

- A rectifier is an electric instrument which transforms AC (alternating current), to DC (direct current) [33].

- An inverter, or power inverter, is an electronic instrument or circuitry which converts direct current (DC) to alternating current (AC) [1,33].
- A DC-to-DC converter is an electromechanical instrument or an electronical device which transforms a source of direct current(DC) from one voltage level to another. It is a kind of electrical power converter. Power levels range from very low (small batteries) to very high (high-voltage power transmission) [34].
- A solid-state AC-to-AC converter transforms an AC waveform to another AC waveform, where the output voltage and frequency can be set arbitrarily [35].

3.4.4 Inverters

In a PV system is considered the inverters the second most important part. Not only that but also the PV panels are the most expensive and significant. Inverters form 15 - 25% of the complete PV system cost in a domestic off-grid system and 5-10% of the complete PV system cost in a mercantile field on-grid system. The inverter depends on power electronics circuitry to convert DC power to AC power. There is a transistors based bridge in the inverter which normally consists of transistors like insulated-gate bipolar transistors (IGBT) or mosfets. The blocking and conducting state of these transistors which are run at high switching frequency (2-20 KHz) are resulted sinusoidal AC at the frequency of 50 or 60 Hz via a help from a filter. In addition there is controller in inverter which uses algorithms which manage the transistors based bridge and also supplies maximum power point tracking. In the inverter for separating it safely from the grid, there are switches on both DC and AC aspects. In addition there are also over-current protection circuits on both aspects like fuses or circuit breakers.

The inverters which are used in off-grid systems must adjust AC voltage which is provided to the load which is local and for retaining the system reliable in running that requires a speed dynamic response, since the value of voltage may vacillate from -30% to + 25% of the nominal voltage. Supplying a quick motor inrush current is one of features which must be available and which means a provision a lot of energy during a short duration of time, meanwhile being efficient at marginal power levels. Morever, a charge controller, which controls with the flowing of energy in both directions from and to a storage system, is often integrated with the off-grid inverter. According to regulations regarding electromagnetic compatibility (EMC) and electric safety codes have to be chosen the inverter. The efficiency of the PV inverter is one of its significant features. When the power is at low ranges, the inverter is usually inefficient, but the efficient increases and arrives a peak in the midst of the energy level, and then decreases at higher energy ranges. Furthermore, the efficiency changes at several DC voltage ranges. The suitable size of inverter should be chosen to be the acquired energy from the PV panel lower than the power rating of the inverter [31].

3.4.5 Generator

Generator is a mechanical instrument which converts mechanical power into electric energy [36]. In this study, it will be used in emergency cases when all the sources of power are not available and the batteries are not charged or in maintainance cases.

3.4.6 Other Components

The completion of system requires all the wiring, grounding connectors, combiners, switchgear, fuses etc. These elements must be made of strong material, because they must bear tough weather cases which would cause e.g. rust. All these components have to be sorted for dealing with true current and voltage sort and the wires have to be sustainable enough [1,5,6].

3.4.7 Load

It is the device which is responsible for consuming this power and convert it into work. The difference, quantity and complication of the behavior of the loads which could be tied to a crossbred clean energy system make complicated to be modeled [1].

CHAPTER 4

SCADA SYSTEMS

4.1 Introduction

Industrial control system (ICS) is a public idiom which includes various kinds of control systems, encompassing Programmable Logic Controllers (PLC) which is often existed in sensitive infrastructures and the industrial sectors, supervisory control and data acquisition (SCADA) systems, and distributed control systems (DCS). ICSs are utilized in manufactures like gas, electrical, oil, and water, transportation, pulp, chemical, paper and pharmaceutical, beverage and food, and discrete manufacturing (e.g., durable goods , aerospace, and automotive.) [39].

The shortcut of SCADA is 'Supervisory Control and Data Acquisition'. The main task of SCADA is for acquiring data from far equipments like pumps, transmitters, valves etc. and supplying chiefly control remotely depending on a SCADA host software platform. This supplies operation control locally for this reason these machines turn on and off at the true time, supplying the support for the strategy of your control and a remote method of capturing events (alarms) and data for observation these operations. SCADA host platforms also supply tasks for historical storage of data, alarming, graphical displays, and trending [38].

They are computer depended on control systems that control and observe industrial operations that exist in the physical world. SCADA systems can be existed in oil addressing and production, pharmaceuticals, industrial facilities, power, distribution, water treatment and the list goes on. They are the best control way for operations that have huge quantities of data which require analyzing and gathering or need sensitive control in fast paced operations, or are expand on far distances [37].

In the other way, SCADA systems are very distributed systems utilized to control geographically scattered assets, often dispersed over a large number of square kilometers, where localized control and data acquisition are sensitive to system process. They are utilized in distribution systems like wastewater collection systems and water distribution, gas and oil pipelines, railway transportation systems and electrical energy grids. A SCADA control center accomplishes localized observing and control for field sites over far-distance communications networks, including addresing status data and observing alarms. Depended on data received from far stations, operator-driven or automated supervisory instructions can be pushed to far station control equipments, which are often referred to as field instruments. Field instruments control domestic operations like closing and opening breakers and valves, gathering data from sensor systems, and observing the native milieu for alarm circumstances [39].

4.2 SCADA Systems

SCADA systems are utilized to control scattered assets where localized data gathering is as worthly as control [40,41]. These systems are utilized in distribution systems like wastewater gathering systems and water distribution, gas and oil pipelines, distribution systems and rail and electrical utility transmission and other public transportation systems. SCADA systems integrate data gathering systems with data transmission systems and HMI software to supply a localized observing and control system for numerous operation inputs and outputs. SCADA systems are prepared to gather field data, transmit it to a central computer facility, and display the data to the operator graphically or textually, thereby giving a permission to the operator to observe or control a whole system from a central location in real time. Depended on the sophistication and setup of the individual system, control of any individual system, operation, or task can be automatic, or it can be accomplished by operator instructions.

SCADA systems contain both software and hardware components. Standard hardware encompasses an MTU (Master Terminal Unit) which its position is at a centre of control, communications equipment (e.g., telephone line, cable, satellite or radio), and one or more geographically distributed field sites contain either a PLC or an RTU , which controls actuators and/or observes sensors. The MTU addresses and saves the data from RTU outputs and inputs, while the PLC or RTU controls the domestic operation. The communications device give a permission for the transmit of data and information back and forth among the PLCs or RTUs and the MTU. The software is programmed to inform the system when and what to observe, and what echo to initiate when parameters go outside passable values and what ranges of parameter are passable. An IED (Intelligent Electronic Device), like a protective relay, may communicate immediatly to the SCADA master station, or a domestric RTU may choose the IEDs to gather the data and send it to the SCADA master station. IEDs supply a immediate interface to observe equipment and control and sensors. IEDs may be immediatly chosen and controlled by the SCADA master station and in most states have domestic programming that gives a permission for the IED to work without immediate instructions from the SCADA control center. SCADA systems are generally prepared to be fault-tolerant systems with big repetition constructed into the system structure.

4.3 SCADA Systems Signals

In SCADA systems, there are a lot of components which send and receive many types of signals that give the SCADA systems the capability to acquire data and contro the system to achieve the required tasks. The types of signals in SCADA system is abbreviated to two main kinds.

The first type of signals is:

- DI – Digital Input.
- DO – Digital Output.

Digital or Discrete signals supply an ON or OFF input to a SCADA system. These signals just take two values either one or zero such as a switch which is either operned or closed. They are the same binary signals which are utilized in computer processors.

The second type of signals is:

- AI –Analog Input.
- AO –Analog Output.

Analog signals are signals which have changing values in continuous form. According to this change, a new change in the suggested system. In the other way, a change in signal value indicates to change in the parameters being observed. For examples, pressure and temperature are analog signals. The format of signals which are produced by the instruments and are being observed by a SCADA system are current or voltage depended such as: 4-20 mA, 0-20 mA, 1-5VDC, 0-5 V DC, -10V DC to 10 V DC...,etc [37].

4.4 SCADA System Components

The implementation of SCADA systems need to understand the four sensitive components of each system. SCADA systems are generally utilized in several manufactures to observe and control equipment in far or dangerous places. Every system is equipped with various parts which are sorted to four basic components [43]:

- Sensors or Field Instruments.
- PLC (Programmable Logic Controller)/RTU (Remote Terminal Unit).
- Central Computer Station including HMI Software – Proprietary for specific RTUs or open including interfacing many products.
- Communications Link – open standard (like MODBUS) and proprietary.

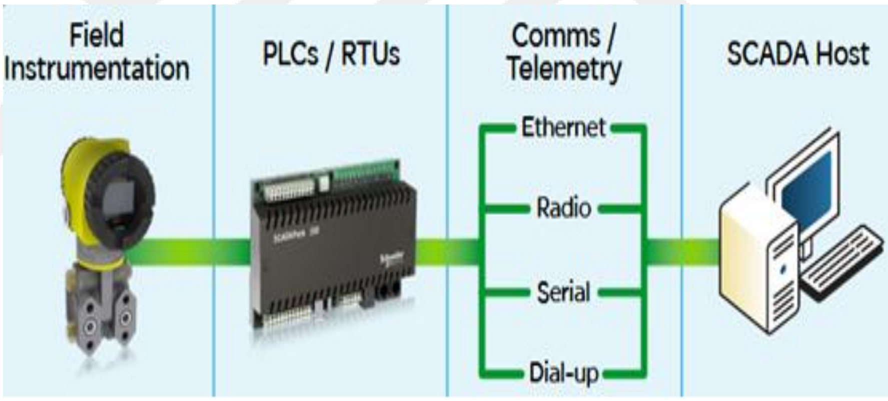


Figure 4.1 SCADA system overview

4.4.1 Field Instrumentation

In every system, the need to control some thing that means the need to measure some thing in that system. According to that, the instrumentation is a main item of an optimized and safe control system. Previously, valves and pumps were controlled by manual. At that time, an operator would start/stop pumps manually and valves would opened/closed by hand. Bit by bit, these instruments have been connected with sensors as a feedback, like Level sensors and they have been connected by wire to a domestic RTU or PLC for transfering data to the SCADA host software.

	Early instrumentation	Feedback sensors	Add Actuators
Pro	Installation is cost-effective	Central view	Central control
Con	Expensive to operate	Still expensive to operate	Higher technical requirements

Figure 4.2 Progress of instrumentation

Although today's device technician needs more technical familiarity and the capability to pattern, keep maintaining equipment and install, than previously, that is alleviated by the lower cost in automating operations and big technical proficiencies held by personnel. In these days, the majority of field instruments like valves have been provided with actuators, authorizing a PLC or RTU to control the machine rather than depending on manipulation which is done by hand. This type of ability means the control system can interact more to improve production or shutdown under unusual events quickly. In idioms of regulatory compliance, device for the gas & oil industry has already established to comply with dangerous class, group and division sortings. The requirement is that the instrument must be prepared for the area or location in that it has been put, e.g. an milieu where the presence of explosive vapors within usual operating conditions, or within unusual circumstances, are known.

There are a lot of cases where the device is also needed to work in cruel milieus. There are many kinds of device are prepared for harsh circumstances of cold and hot. If the device is not prepared for these conditions, an artificial milieu within a cabinet or some sort of building is needed. This is a result of an surpluse cost not only in initial styling but also for continuous maintenance.

Device must also be compatible with any EMC (electromagnetic compatibility) norms that may be in position, to guarantee that an electrical equipments does not have any unwanted impacts upon its milieu or other electrical equipments within its milieu [38].

Depending on the above, it will be mentioned some types of devices which can generate discrete signals like [37]:

1) Limit Switches

Definition of a limit switch is a switch operated by the movement of a machine component or existence of an object.

They are used for controlling machinery within a control system , as a security interlocks , or even to count objects passing a true point. A limit switch can be an electromechanical gadget which includes an actuator mechanically associated with a couple of contacts. When an object makes connection with the actuator, these devices operates the contacts to create or break a power connection. Because of the ruggedness of some a variety of milieus and applications the limit switches are used in, ease of set up, and reliability of procedure. They can determine the absence or presence, moving, positioning, and end of travel of an object. These were utilized to define the border of trip of an object first and depending on that the name "Limit Switch" came [47].

Figure 4.3 Limit switches

2) Pushbuttons

A push-button (also spelled pushbutton) or just button is a straightforward switch system for controlling some fact of a machine or an activity. Buttons are created out of hard materials typically, plastic or metal usually [45].

Figure 4.4 Pushbuttons

3) Float switches

A float switch is a kind of level sensor, a gadget utilized to determine the amount of liquid inside a container. The switch enable you to control a pump, as an indicator, an alarm, or to control other instruments. One kind of float switch utilizes a mercury switch in the a hinged float [46].

Figure 4.5 Float switch

4) Flow switches

These switches are utilized to observe and display gassy media and the flow of liquid. The devices include a functional security and high switching precision, continuous switch point setting and low switch hysteresis by the operator [48].

Figure 4.6 Flow switch

5) Relay contacts

Relays are switches which open up and close circuits electronically or electromechanically. Relays control a single electrical circuit via opening and closing contacts in different circuit. When a relay contact is Normally open (NO), there can be an open contact when the relay is not active. When a relay contact is Normally Closed

(NC), it exists a closed contact when the relay is not active. In these cases, applying electric current to the contacts will substitute their case. Relays are normally utilized to switch teeny currents in a control circuit and do not generally control power consuming instruments except for non-big motors and Solenoids which draw low amps. Nevertheless, relays can "control" bigger amperes and voltages by having an amplifying impact because a teeny voltage that is given to a relays coil can produce in a big voltage being switched by the contacts. Protective relays can protect the equipment from damage by determining electrical oddity, including overloads, invert currents, overcurrent and undercurrent. Not only that but also, relays are vastly utilized to switch starting coils, audible alarms, pilot lighting and heating elements [49].

Figure 4.7 Relay contact

6) Selector switches

Selector Switch works on a public precept; they include a simple selector switch on the front of the panel, and a wide range of prospective contact combinations (by the contact blocks), on the inside of the enclosure. The main difference between the the pushbutton and selector switch is that, while a pushbutton has a plate that pushes down both contact plungers simultanesously, a selector switch has a rotating cam with ridges and flats, permitting to actuate the plungers independently [44].

Figure 4.8 Selector switch

On the other hand and according to signals types, there are equipment that generate analog signals which SCADA systems deal with them. For examples, temperature sensors, pressure sensors, Level sensors....,etc.

4.4.2 RTUs and PLCs

The SCADA system contains an important part which collect data from devices, converts the data which can be read and understood by computer and addresses high speed communication. This part is PLC (Programmable Logic Controller).

In 1968, the PLC (Programmable Logic Controller) was concocted for backing the automobile manufacture by Bedford Associates' engineer Dick Morley. The first generation of PLC was named a MODICON (MODULAR DIGITAL CONTROLLER).

Day after day, variations of the PLC have developed. The two primary ones are:

- RTU – Remote Telemetry Unit.
- PAC (Programmable Automation Controller) or one type of the PLC (Programmable Logic Controller).

The Remote Telemetry Unit (RTU) was designed to collect data and then send this data to a far processor. A RTU has connections abilities of a PC and the IO ability of a PLC, as well as being manufacturing hardened. Even though, it does not control operations utilizing an inner program. It works as a data logger which can transfer data at a specific time to base controller. A hybrid version of the RTU includes a PLC which control domestic operations and accomplishes the communication tasks of a RTU.

The othe generation of a PLC is a PAC which has the same form and task as a PLC. This device has a processor which is more associated to a computer in its computing techniques and speed. The most important advantage of PAC is the communication task which give it a permission to run more competently with modern communication networks which are depended on Ethernet [37].

Remote Telemetry Units (RTUs) and Programmable Logic Controllers (PLCs) utilized to be clearly different equipments but day after day these differences hide. This has been a interchange of technology as industrialists of these devices improved their abilities to meet market requests.

Thirty years ago, an RTU was a ‘dumb’ telemetry box for connecting field devices. The RTU would ‘relay’ the data from the devices to the SCADA host without any addressing or control but had well-advanced communication interfaces or telemetry. After some years, exactly in the 1990s, the manufacturers added a control programming to the RTU for that it became more like a PLC. On the other hand, PLCs could always do the control program but the communication interfaces were lacked and data logging ability, that has been added recently.

A further evolution of instruments in the field is to offer a specific application that could combine a number of devices and instruments with an RTU/PLC, combining technology sets to supply an ‘off the shelf’ way to common operation demands, e.g. gas well production which encompasses flow measurement, elements of observing, and control which would expand as an asset into the SCADA host.

In idioms of ecological and regulatory subjugation, RTUs and PLCs have the similar kind of demands as device in that they run in the similar milieu. Even though, PLCs have traditionally not been as environmentally compliant as RTUs. This is fundamentally because of the fact that PLCs were prepared to run in places, like factory floors, where the milieu was previously conditioned to some degree [38].

4.4.3 Remote Communications Networks

The far communication network is important to transfer information from far RTU/PLCs, that are out in the area or extended with the pipeline, to the SCADA host situated at the central control center or field office. With assets distributed over a large geographical distance, communication is the linking part or the glue of a SCADA system and fundamental to its process. How well a SCADA system can administer communication to far assets is essential to how succeeded the SCADA system is.

Before 20 years, the communication network would have been rented lines or dial-up modems that were very costly for installing and maintaining, but recently many consumers have switched to satellite or radio communications to decrease costs and cancel the problematic cabling troubles. Lately, other communication kinds have been made available which encompass cellular communications and improved radio instuments which can help better diagnostics and higher communication averages.

Even though, the truth that these kinds of communication media are still prone to washout is a base trouble for distributed, modern SCADA systems.

When the communication medium altered, the protocols changed too. Definition of Protocols is electronic languages which RTUs and PLCs utilize to interchange information, either with other RTUs and PLCs or SCADA host platforms.

Previously, protocols have been the product of a single manufacturer and proprietary. As a further evolution, many industrialists attracted to a one protocol, MODBUS, but added on proprietary components to face specific tasks demands. In the industry of the Gas & Oil, there are a number of variables of MODBUS, encompassing but not limited to, MODBUS ASCII, MODBUS RTU, Enron MODBUS and MODBUS/TCP. This supplied a communication norm for the recovery of flow or address information from a specific PLC or RTU.

This increasing development in utilizing MODBUS protocol variables was seen as an advance, but it still connected a user to a specific industrialist, that is very much the state in these days. A good example is how historic flow information is recovered from a RTU/PLC by a SCADA host. Even though, the improvement of SCADA host software, and in some states the participating of protocol languages, has indicated that number of the troubles with proprietary elements have been further solved.

Recently, protocols have seen the light that are really non-proprietary, like DNP (Distributed Network Protocol). These protocols have been generated independently of any single industrialist and are more of an manufacture norm; many persons and industrialists have participated to their evolution and subscribed to these protocols. Even though, these protocols have yet to improve significantly enough to have a broad appeal to the application operation and arrangement demands for gas & oil markets. Therefore, the gas and oil shop is still heavily invested in MODBUS variables. These protocols have benefits which are more obvious to clients, it is anticipated that they will be more easily acceptable and are a element of norm solutions supplied specifically for gas and oil markets [38].

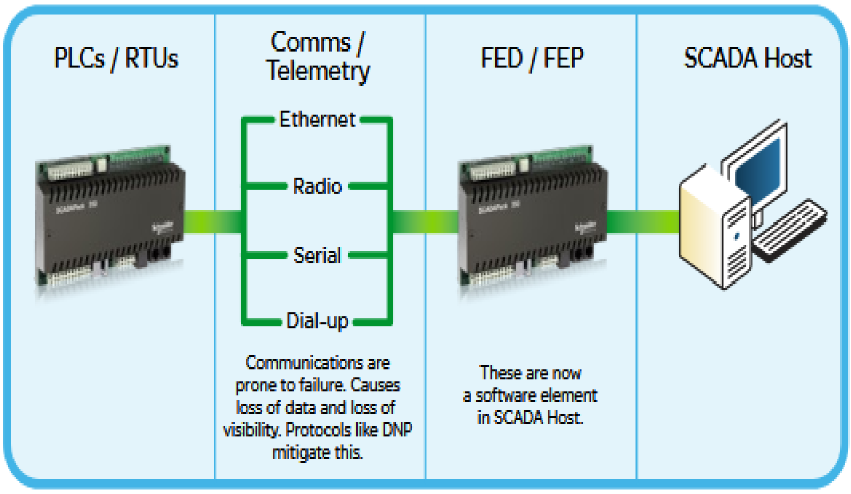


Figure 4.9 Wide area network SCADA

4.4.4 SCADA Host Software

The SCADA systems depend on gathering the data from the field of work and the operator can access into this system by some technics which can sort into two technics:

• HMI – Human Machine Interface.

• OIT – Operator Interface Terminal.

OIT's supply a domestic interface, specially in a far position or into a separated system. Screens have a simple design to display data since displays are not big from 4 inches to 14 inches which can put anywhere .

HMI software is utilized at the base control position. Software is set up on computers with higher performan processors and bigger screens which offer more data. They also benefit animation to concentrate operator attention, annunciate an alarm or confirm sensitive data to significant places of a operation [37].

Commonly, SCADA host software has been the technicality to sight trends, graphical displays and alarms. The control of SCADA host itself only became existed when control components for far devices became advanced. They seperated these systems from the out world and became the field of engineers, technicians and operators. Their liability was to engineer operations, observe and maintain and SCADA components. The Information Technology (IT) developed and the case is no longer. A lot of stake holders now need real time incoming to the information which the SCADA host software gives. Maintenance management, accounting and material purchasing demands are achieved or partly achieved from data generated from the SCADA system.

Therefore, there is a drive for the SCADA host to be an Enterprise structure supplying data to a many different clients and operations. This has motivated SCADA host software advancement to espouse norms and technicality to help interfacing to these systems. This indicates that IT, commonly isolated from SCADA systems, is participated in supporting to maintain networks, database interfacing and client access to information.

A lot of the initial products of SCADA host were improved specifically for the industrial milieu where a SCADA system established inside a single building or complicated, and SCADA systems for geographically distributed assets did not have a lot of the telemetry communication properties.

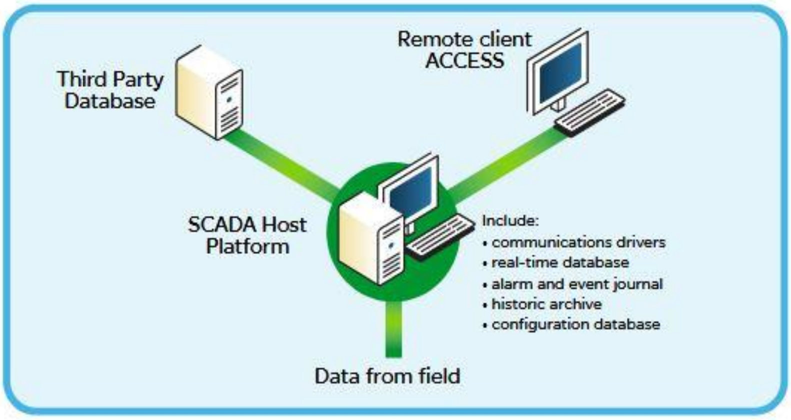


Figure 4.10 SCADA host platform

These kinds of first generation SCADA hosts needed a hybrid RTU or PLC, called a Front End Processor (FEP) or Front End Driver (FED) most of time , to be utilized for handling communications with far instruments. This conducted in a many of cons as it needed external to the SCADA host platform, created a communications bottleneck and specialized programming. In spite of many FEP or FED instruments processed some of this, there were difficult things in creating and maintaining them because of their specialized architecture and supplemental costs. Modern SCADA software which includes far functionality no longer needs these kinds of hybrid PLCs that were designed for communications. They now utilize software programs called ‘drivers’ that are incorporated into the SCADA host itself. Software drivers include the different kinds of protocols to connect with far instruments like PLCs and RTUs.

As a result of development of technology, SCADA host software platforms became capable to benefit of many new properties. These encompassed the improvement of integral databases exactly prepared for SCADA host software demands, being capable to deal with thousands of events a second, for actually large systems, yet still adapt to norm database interfacing like Object linking and Open Database Connectivity (ODBC) and Embedding for Databases (OLE DB). These norms are needed for this cause third-party databases can access data which is existed in the SCADA host software. Far user access to the SCADA host is another technology which has enabled clients to run and observe SCADA systems during the move among or at other positions [38].

4.5 Generations of SCADA Systems

The SCADA system consists of many components and Depending on the architecture of SCADA systems, they were divided into many kinds. The basic four generations of SCADA sytems are [42]:

1. First Generation: Monolithic or Early SCADA systems.
2. Second Generation: Distributed SCADA systems.
3. Third Generation: Networked SCADA systems.
4. Fourth Generation: Internet of things technology, SCADA systems.

1. Monolithic or Early SCADA Systems

Minicomputers are utilized earlier for processing the SCADA systems. In earlier days, within the time of first progeny, monolithic SCADA systems were created wherein the mutual network services were not existed. Hence, they are freelance systems which do not have any connection to else systems.

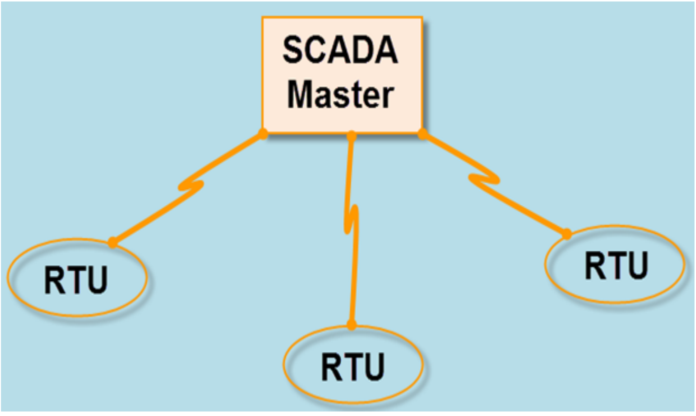


Figure 4.11 Monolithic or early SCADA systems

All the far terminal unit places would communicate to a back-up central system for performing the first progeny SCADA system repetition, which was utilized in state of fail of the base central system. In the early first generation, the monolithic SCADA systems have tasks which were limited to observing sensors in the system and informing any processes in state of exceeding programmed alarm scales.

2. Distributed SCADA Systems

The participation of control tasks is distributed through the multiple systems tied to each other utilizing Local Area Network (LAN) in the second SCADA generation. Hence, these were called as distributed SCADA systems. These singl stations were utilized to participate real-time data and instructions addressing for accomplishing control functions to travel the alarm scales of potential troubles.

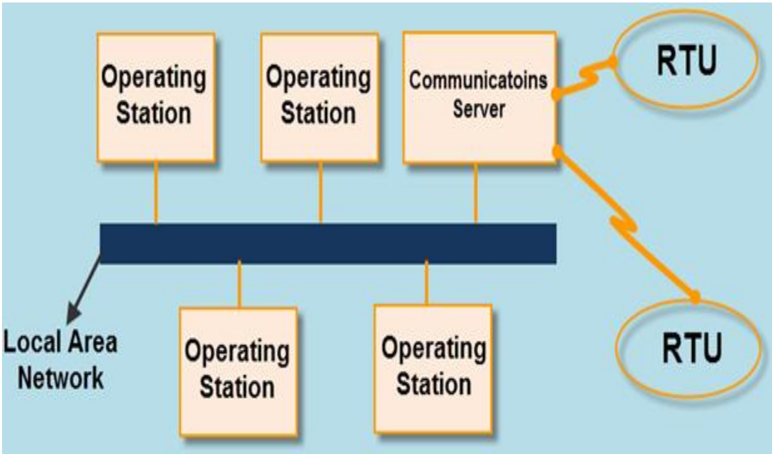


Figure 4.12 Distributed SCADA systems

The size and cost of the station were decreased with reference to the first generation system, as each system of the second generation was taken charge of accomplishing a private function with decreased cost and size, but the network protocols were not united in the second generation systems as well. Some persons in addition to the developers, as the protocols were proprietary, decided the safeness or security of the SCADA installation, but the safeness of the SCADA installation was often neglected.

3. Networked SCADA Systems

Most of the existing SCADA systems are communicated and networked utilizing Wide Area Network (WAN) Systems by phone lines or data. For transporting data among the nodes repeatedly, Fiber Optic Connections or Ethernet is utilized in these systems. Programmable Logic Controllers (PLC) is utilized in the third generation SCADA systems for observing and modifying the routine informing operators only in state of base decisions demands.

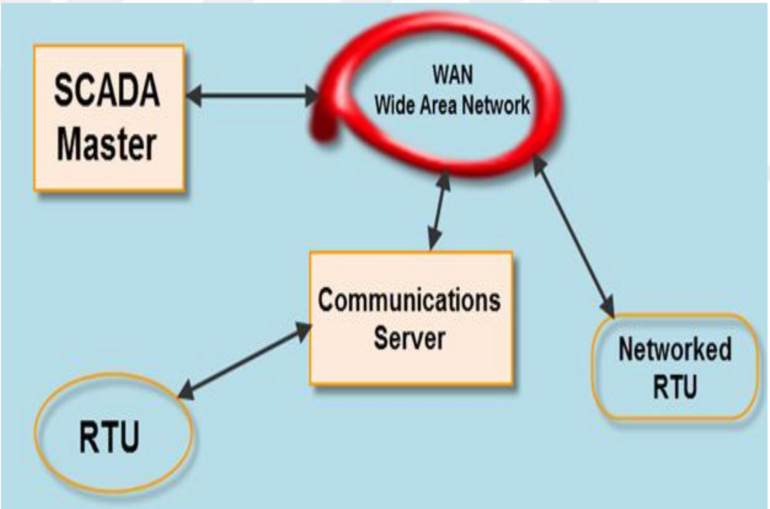


Figure 4.13 Networked SCADA systems

They described the first and second generation SCADA systems as sealed systems because they are limited to single building networks or single place. In these systems, there are not any danger compared to the third generation SCADA system that are tied to the internet which create the security dangers where it will exist several parallel working distributed SCADA systems which work under a one supervisor in architecture of network.

4. Internet of Things

Espousing the internet of things technology, which has the commercially available cloud computing, decreased the infrastructure cost of the SCADA systems in fourth generation. The maintenance and integration of the fourth generation SCADA systems are more easier other generations .

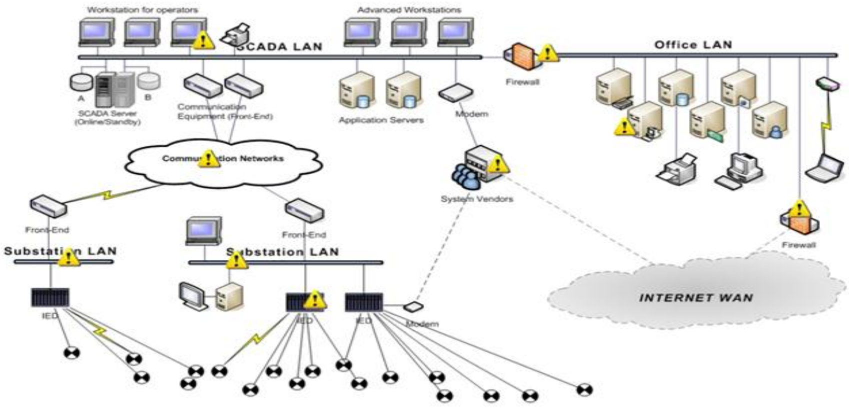


Figure 4.14 Internet of things

The use of the horizontal scale from the cloud computing facility gives the capable to these SCADA systems to report state in real time; so, more complicated control algorithms can be executed that are virtually sufficient to execute on classical PLCs.

The safeness dangers in state of decentralized SCADA executions like a heterogonous combination of proprietary network protocols can be exceeded utilizing the open network protocols like TLS deep-rooted in the internet of things that will supply manageable and comprehendible safeness limits.

CHAPTER 5

CONTROL SYSTEMS

5.1 Introduction

A control system is a system of instruments or group of instruments, which regulates, manages, leads, guides or the conduct of other systems or instruments to perform wanted results. In the other way, the control system can be defined as a system, that controls other systems. Day after day, the human culture is being developed the claim for automation is growing accordingly. Automation highly demands control of instruments.

Recently, control systems takes the base role in the advancement and development of new technology and culture. Some control system practically influence more or less in each side of our daily life. For example, an automatic iron, a bathroom toilet tank, a refrigerator, an automobile, an air conditioner, a geezer all are control system. These systems are also utilized in manufacturing operations for more output. The control system in transportation systems, weapons system, space technology, robotics, power system, quality control of products and many more. The basics of control theory are usable to both engineering and nonengineering areas.

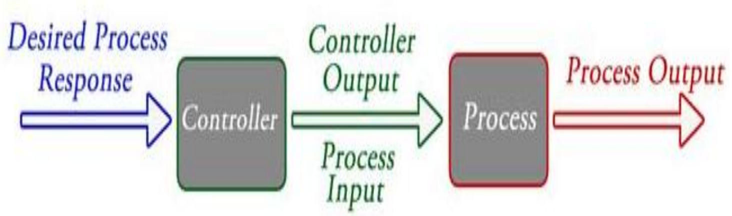


Figure 5.1 The block diagram of general control system

5.2 Types of Controllers

Electronics and Electrical instruments function at different logics, designs and basics. All home base circuits, computers and industrial machines function on various principles. They function according to their load and design. Microcontroller, microprocessor, FPGA and PLC are the names of different types of electronic circuits There are many technics for designing the control systems. It will be mentioned some of them here [51]:

1. Microcontrollers
2. Microprocessor
3. FPGA
4. PLC

1. Microcontroller

A microcontroller is a mini computer on a one circuit. It contains input/output peripheral, processor core and memory. The memory is probably a flash or rom. By the other words, Microcontroller is a small monocular circuit system utilized in embedded systems, automatically controlled equipment, toys, office instruments, medical equipment and far controls [51].

2. Microprocessor

A microprocessor is an incorporate of central processing unit. Essentially, a microprocessor deals with the data which comes from input and processes it to implement the required instructions. It saves this data into the memory and display the results of implementation through an output or displays. By the other words, It is a multi objectives programmable circuit. It can be designed on a single circuit or some a little integrated circuits. These microprocessors deal with symbols and numbers that are in the binary language which is called machine language [51].

3. FPGA

The shortcut of FPGA is a Field Programmable Gated Array. It is an integrated circuit which is produced to be configured by the designer or user after it manufactured. Generally, a programming and configuration of this device is descibed as a hardware description language [51].

4. PLC

PLC is a logic controller that can be programmable. This means that PLC represents a digital computer utilized for industrial machines such as electromechanical industries and automation. It is utilized to control factory assembly lines, amusement rides etc.

This device is designed with a multi inputs and outputs. Not only that but also it is created with higher possibilities like unaffected to electronic vibration and noise and expanded temperature range [51].

- **PLC vs FPGA vs Microcontroller vs Microprocessor:**

There are many differences between PLC, microcontroller, microprocessor and FPGA, but here it will be mentioned the main difference among them. The difference between microprocessor and microcontroller is that, microprocessor is a multiple integrated central addressing unit that may address, display data by output and conserve information. It is a multi objective instrument. On the other hand, microcontroller is a monocular circuit small instrument which includes processor, memory, core and an output unit. It is utilized in small applications and for one objective [51]. The difference between FPGA and PLC is, PLC is device with a multi inputs and outputs which may be considered as a digital compute which is utilized for controlling in heavy applications and factory machine lines, but FPGA is an programmable array that can be configured after producting [50]. FPGAs are instruments which now permit the normal person to produce the own digital circuits. This person is the one designing the circuit. The processor is not existence to run software on, until the designer can engineer one [52].

5.3 PLCs

The Programmable Logic Controllers (PLCs) are one of the computer families which are generally known as programmable controllers. They are utilized in many tasks like industrial and commercial applications. A PLC observes inputs, takes decisions depended on its program, and gives commands to outputs for automate a machine or operation [53].

A programmable logic controller was fabricated for replacing the sequential relay circuits that are fundamentally used for machine control. Applications of PLCs in automation are in the area of data management, , sequence control, communication, operation control and motion control. Generally, most of the PLC uses are still applied in sequence control machine control and material handling applications. On the other hand, it is growing the use of the applications of process control which are depended on PLC. In addition to performing basic tasks such as counting, timing and sequential process, PLCs can also achieve arithmetic processes. PLCs have special modules which deal with analog control tasks such as P, PI and PID positioning control as well. PLCs can supply data on machine status, machine malfunction, alarm messages, production summary, alarm limit detection...etc [6,57].

PLC is considered the most mutual approach in industrial implementations, thus that they have a good properties like connecting them easily with actuators and sensors of any type to endure various conditions, possibility of electrical connection simply, possibility to learn the programming of device without difficulties and possibility of work at hard work conditions such as humidity, noise, vibrations and temperature. There are different types of PLC that cover most industrial implementations which differ from each other in possibilities such as the number of inputs and outputs, storage size of memory and processing speed, that creates a difference in their qualifications which affects on the cost [6,56].

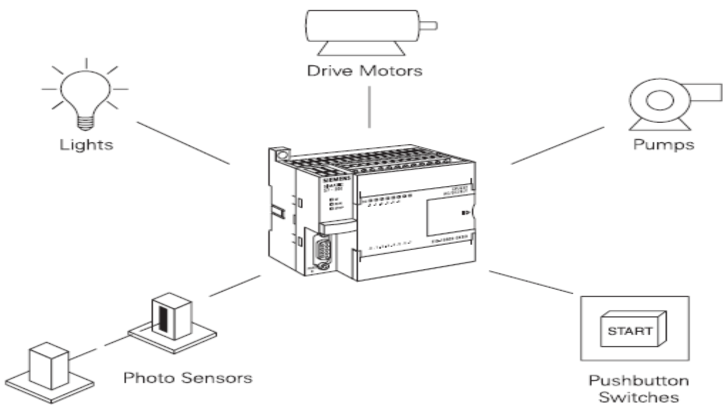


Figure 5.2 General system of PLC

5.4 Basic Components of PLC

PLCs are composed of a Central Processing Unit (CPU), inputs and outputs. These inputs receive either digital signals or analog signals from different field instruments (sensors). After that they convert them into machine language or ,by the other words, into logical signals which can be understood by CPU which processes the coming data from sensors to take suitable adecisions dependin on the control instructions which are stored in the memory. Afte that, Output modules take the coming commands or instructions from CPU and translate them into analog or digital signals which can be utilized to control different field instruments (actuators). A programming instrument is utilized to load the required instructions which form the program to PLC. This program decide the work of PLC for a specific input. An operator interface instrument displays the information of process and if there are a new control parameters, it permits to be entered [53].

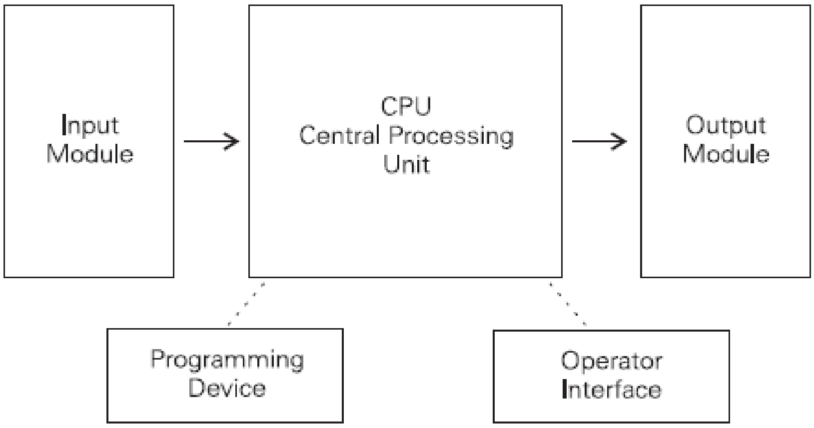


Figure 5.3 Basic components of PLC

For example, Pushbuttons (sensors) connected to PLC inputs which can be utilized to start and stop a motor which is connected to a PLC output through a motor starter (actuator).

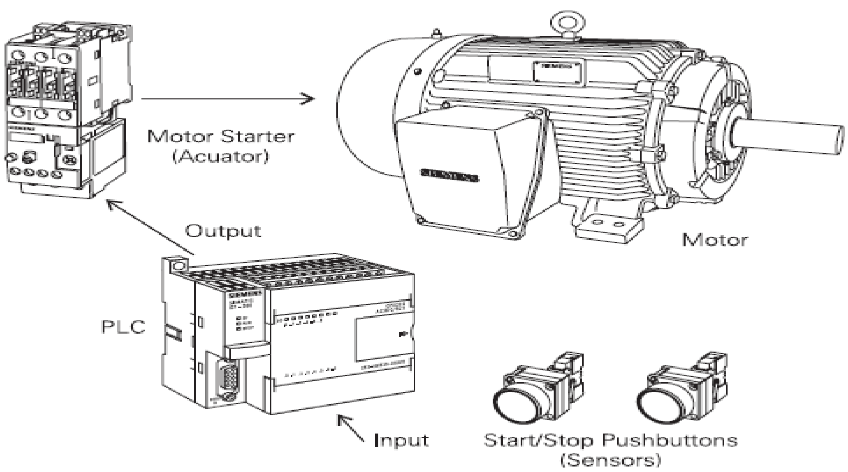


Figure 5.4 Simple example of PLC

5.5 Basics of PLC Operation

The PLC program is implemented as part of a repeated operation indicated to as a scan. Reading the status of inputs via the CPU is the first step of scan. According to the status of the inputs, the loaded program on PLC is implemented. After finishing the program, the CPU achieves communication functions and internal diagnostics. The update of status of outputs ends the scan cycle, afterwards the operation starts again. The size of the program, amount of required communication and the number of I/Os determine the cycle time [6,53].

Figure 5.5 Scan cycle of PLC

5.6 PLC Languages

PLC is an electronic instrument which observes the operations via receiving the input signals from the system, then it sends the commands to the outputs according to a collection of orders which are programmed by utilizing PLC progragramming languages which are five and it is selected one of them for the work.

The programmable controller programming languages are sorted to five programming languages by IEC 61131-3 which is a international norm. The list of programming languages which is given by this norm [54]:

1. Ladder diagram (LD).
2. Sequential Function Charts (SFC).
3. Function Block Diagram (FBD).
4. Structured Text (ST).
5. Instruction List (IL).

The most important benefit from this norm is that gives a permission for using many languages for programming the same programmable controller. This permits to the program developer for choosing the best suited language to required task [54].

5.6.1 Ladder Diagram

LD language,Ladder logic or Ladder diagram which is a kind of programming languages of PLC which may be learned easily because it is a visual programming language. In addition to the classification of LD by IEC-61131-3 norm for logic controllers which is programmable, this means that LD is international language. The good representation of discrete logic, possession good debugging tools and intuition of LD made this language the most common kind of programming languages which deal with PLC. One main disadvantage of the LD is that it is counted one of programming languages which has weak data architecture because of unorganized data well e.g., the variables is potentially to be generated by the language which possess interlocking memory sites. Consequently, unforeseen troubles may be occured.

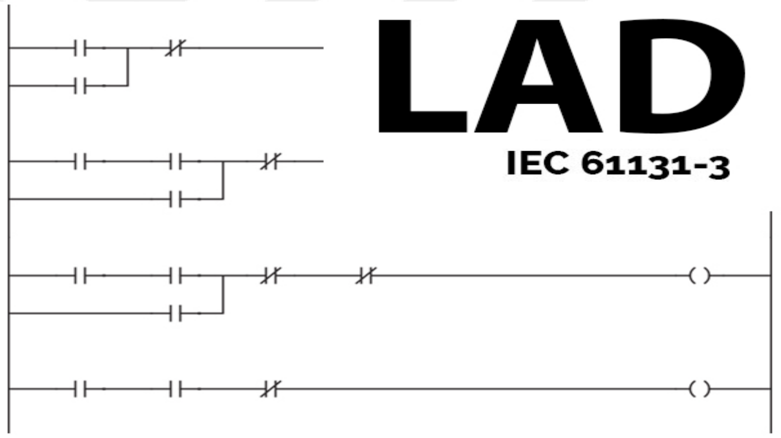


Figure 5.6 Ladder diagram

5.6.2 Charts of Sequential Functions (SFC)

The other type of programming language of PLC is SFC which is like ladder language which is graphically oriented. In addition to, it permits the programmer to program in chronological order. SFC has advantage of understanding due to possibility of envisage the occuring thing and its occuring time in the code procedure. It is just implemented the active SFC code parts, by this way modifying the code in addition to troubleshooting it become simpler, if troubles happen.

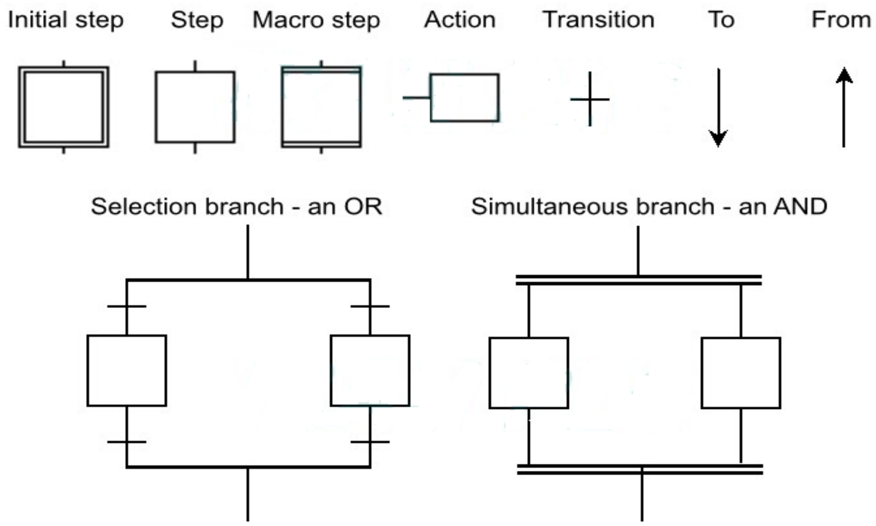


Figure 5.7 SFC language

5.6.3 Function Block Diagram (FBD)

Function block diagram (FBD) is considered a graphic language which directs the data of inputs towards outputs by transmitting them as nested data across blocks, that was invented to ameliorate on the older ladder diagram programming language and textual programming. FBD programming consists of variables, keywords, identifiers and data kinds. The programmer can sight the signals flow among the addressed elements in the system, if FBD gives a permission for that. FBD describes the control logic and loops with techniques which cannot be described with other PLC languages.

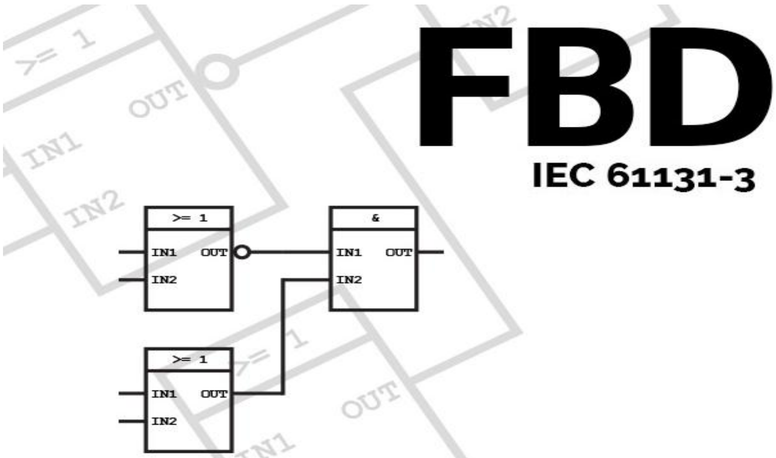


Figure 5.8 FBD language

5.6.4 Structured-Text language (ST)

The fourth kind of programming language, which is used by PLC, is ST (Structured-Text) that entirely depends on text. ST is similar to programming languages such as Pascal and Basic which utilize While,For and If-Then-Else. Thus, it will be easy to program by using this language if the programmer used it before. The experienced and novice programmers can understand ST easily because the statements clarify the way of program work and mechanism of implementation of tasks.

```
 x : BOOL;

 P_STEP : INT;
END_VAR

P_STEP := 3;

CASE PROGRAM_STEP OF
 1: P_STEP := P_STEP+1;
 2: P_STEP := P_STEP+2;
 3: P_STEP := P_STEP+3;
ELSE
 PROGRAM_STEP := PROGRAM_STEP+10;
END_CASE;

LIMIT_SWITCH1 := TRUE;
LIMIT_SWITCH2 := FALSE;

IF LIMIT_SWITCH1 OR LIMIT_SWITCH2 THEN
 OUTPUT5 := FALSE;
 P_TRIGGER := TRUE;
END_IF;
```

ST
IEC 61131-3

Figure 5.9 ST language

5.6.5 Instruction Lists (ILs)

IL is not graphical but is a series of text instructions like assembly language. Because of low overhead of IL, it is known for executing quickly. The main disadvantage of this language is that is not popular as same as other PLC languages [55].

```
        LD      ZAB.Q
        JMPC    mark

        CAL     ZAB(IN:=FALSE)
        LD      TIME_IN
        ST      ZAB.PT
        CAL     ZAB(IN:=TRUE)
        JMP     end

mark:
        CAL     ZAB
end:
        LDN     ZAB.Q
        ST      OK
        RET
```

Figure 5.10 ILs language

CHAPTER 6

THE PRACTICAL STEPS FOR IMPLEMENTING THE SUGGESTED SCADA SYSTEM

Generally, SCADA systems need a lot of components which work an integrated manner for achieving the required task perfectly. Selection of these components depends on many factors which should take in consideration such as budget of the required project, performance which must be achieved by the suggested system which in turn depends on the aims of project and desire of client, the required time for accomplishing the required task, the sufficient for the current function and for future work if the client wants to develop the system, and the power which may be consumed by the system. This selection divides into two parts, the first one is a hardware selection which include talking about the HMI, controllers, actuators and sensors and the second one is a software part which is used for programing the controllers and screens and for testing the system before applying it in real time which saves the time and money.The suggested SCADA system will be achieved by software after choosing the hardware components.

6.1 Hardware Components

It may be depended on any trademark in our project which produces the HMI and logic controllers and that can provide the necessary posibilities to test the system before aggregation the hardware components.

6.1.1 Controller

There are many companies which produce several types of PLCs, for example, the SIMATIC® S7 family like S7-200, S7-300, and S7-400 which are produced by Siemens company and there are Delta company which produces PLCs like AH series and Schneider, Mitsubishi companies...etc.

As an example, the S7-300 PLC, which is produced by Siemens, is utilized in complicated applications which need a greater number of I/O points. This type is expandable and modular. The I/O and power supply are separated modules that are connected to the CPU. The choosing type of PLC relies on the complication of the function and possible future expansion [53].

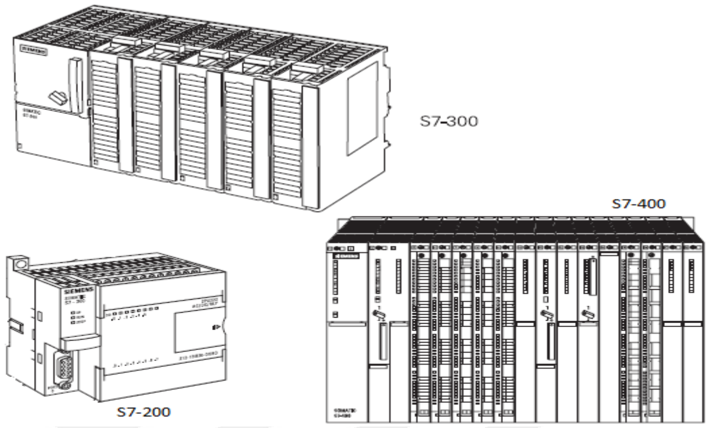


Figure 6.1 SIMATIC S7 family

6.1.1.1 *Structure of the Programmable Controller*

As an example, the SIMATIC S7-300 is a programmable controller which is a modular type which consists of the following components [58,59]:

- Racks which has possibility of accommodating the modules and connecting them to together.
- Power supply (PS) which gives the internal supply voltages.
- Central processing unit (CPU) which saves and addresses the user program.
- Interface modules (IMs) which ties the racks each other.
- Signal modules (SMs) which control actuators by analog and digital signals or befit the signals from the system to the internal signal level.
- Function modules (FMs) which implement time-critical or complex operations independently of the CPU
- Communications processors (CPs) which institute the connexion to subsidiary networks (subnets).
- Subnets which tie programmable controllers together or to other devices.

The power supply, CPU and I/O modules (SMs, FMs and CPs) are plugged into the central rack [58,59]. By simple way, Figure 6.2 illustrates the structure in an S7-300.

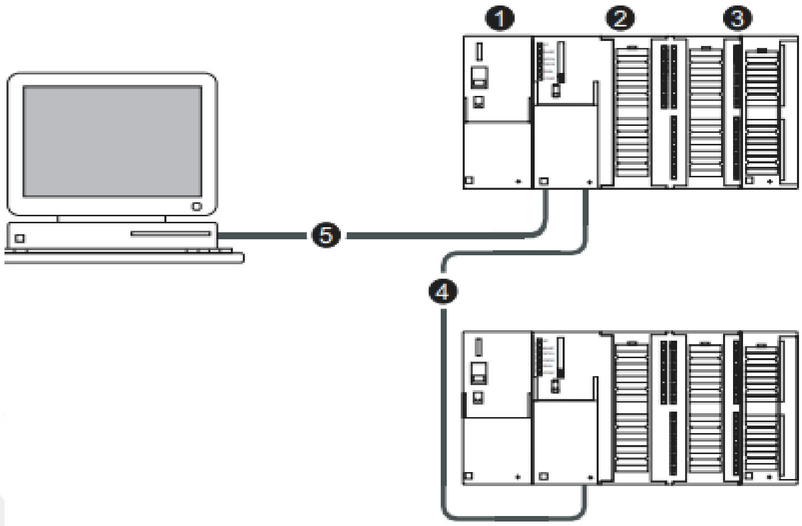


Figure 6.2 The basic structure of programmable controller

According to Table 6.1 which illustates the basic components which were drawn in Figure 6.2.

Table 6.1 The basic Components of the programmable controller S7-300

The number of component in Figure 6.2	The name of component
1	Power Supply(PS)
2	Central Processing Unit(CPU)
3	Signal Module(SM)
4	Profibus Cable
5	Cable for connecting a programming device (PG)

For instance, it may be suggested the following components togather:

A. Power Supply Module PS 307; 10 A.
B. CPU: CPU 313C.
C. SIMATIC S7-300, Analog input.
D. SIMATIC S7-300, Digital output.

A. Power Supply Module PS 307; 10 A.

It may be suggested the PS 307 power supply module (10 A) which has the next important properties [60,61]:

1. Output current 10 A.
2. Output voltage 24 V DC.
3. proof against short-circuit and open circuit.
4. Connection to single-phase AC system (input voltage 120/230 V AC, 50/60 Hz).
5. Reliable isolation.
6. Can be used as load power supply.

Figure 6.3 Power supply (PS 307; 10 A)

B. CPU 313C may be suggested and it has the next features:

1. This CPU has compact CPU with MPI.
2. 24 DI/16 DO.

3. 4AI, 2AO, 1PT100.
4. Three faster counters (30 KHz) integrated.
5. 24 V DC power suppy.
6. 32 KByte working memory.
7. Micro memory card required.

Figure 6.4 CPU 313C

C. Analog Modules

More complicated functions needs the addressing of analog operations signals. Analog sensors and actuators can be tied to a SIMATIC S7-300 by means of analog modules without supplemental elements. The wide range of modules permits the most proper signal module to be chosen for every state.

Analog input modules simplify operation of tying of the controller to the analog signals of a operation. They are proper for tying analog sensors like current and voltage sensors, resistors, resistance thermometers and thermocouples in addition to analog actuators.

The utilization of analog output-input modules supplies the client with the following features [64,65]:

- **Optimum adaptability:** It means that there is ability for expanding the used module by adding the required analog modules for achieving the required task without need to invest in a new system which means that there is no waste of money any more.

- **High-performance analog technology:** There are a high resolution and diversity of input/output ranges which simplify tying of a many analog actuators and sensors.

It may be suggested the following module: SIMATIC S7-300, analog input module [66] which has the next features:

1. Optically isolated.
2. 8 AI ; +/-5/10 V, 1-5 V, +/-20 mA, 0/4 to 20 mA.
3. 16 Bit.
4. 1 Common point (60 V COM.).
5. 4 Channel mode: 10 ms.
6. 8 Channel mode: 23-95 ms, 1 X 40 pin.

Figure 6.5 Analog input module

D. Digital Modules

Digital sensors and actuators can be tied to a SIMATIC S7-300 by means of digital modules. The wide range of modules permits the most proper signal module to be chosen for every state.

The automation system needs digital inputs/outputs which are supplied by digital input/output modules which will be connected with it. For instance, limit switches and pushbuttons can be tied to input modules and contactors and lamps can be tied to output modules.

The utilization of digital input/output modules supplies the client with the next features:

- **Optimum adaptability**: It means that there is ability for expanding the used module by adding the required digital modules for achieving the required task without need to invest in a new system which means that there is no waste of money any more.
- **Flexible operation of connection** : the large diversity of digital sensors and actuators simplifies tying between the operations and the automation system.

It may be suggested the following module: SIMATIC S7-300, digital output module which has the next features [65,68,69]:

1- 16 DO.
2- 24 V DC / 0.5 A.
3- Diagnostics.
4- Redundancy capable.

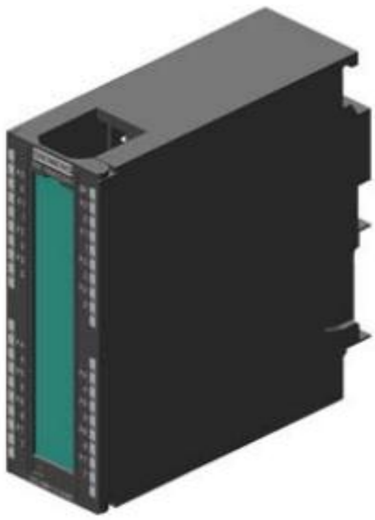


Figure 6.6 Digital output module

6.1.2 Sensors

Sensors are considered ears and eyes of control system. Generally and according to rule which says that the control of some thing means the sense of this thing firstly. Because the function of a controls engineer is often to identify sensors and solve sensing problems.

There are two broad categories of sensors. The first one is digital sensors which give on/off signals, and the second one is analog sensors which give a range of values [70].

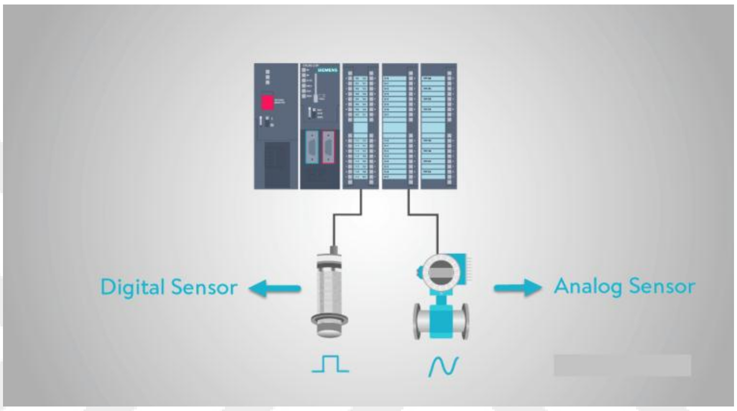


Figure 6.7 Types of sensors

- Digital sensors are by far the most popular utilized sensors in the industrial world. In theoretical idioms, it refers to something which gives one or more bits of data per sensor [70].
- Firstly, limit switches are simple and it may be represented as a contact which can touch off another contact when something get where it is assumed to stop. These sorts of sensors may be utilized for anything which it is divided into two status like Off and on, false and true, Isn't and Is. For instance: Power On, In Position, Running, Full and Empty.
- Proximity sensors, is named "proxes", are utilized for detecting close metal materials by utilizing magnetic fields. In several milieus like in position sensing applications are replaced proximity sensors instead of limit switches.
- Optical sensors, comparing with proximity sensors, have a much longer range, but they are oversensitive to dirt and other ecological and mechanical problems due to utilizing light for sensing.

- There is an other type of sensors which works like proximity sensors,they are capacitive proximity sensors but the difference between them is that capacitive proximity sensors are susceptible to pollution and historically have not been very trustworthy for detecting non-conductive materials.
- Ultrasonic proximity detectors find out solid materials utilizing high-frequency sound but they are very sensitive to dirt and environmental circumstances.
- An auxiliary contact helps a relay and may be considered as a part of a relay. They tell us if the controlling of relay has turned it on or off.
- A push button detects the operator's action.

Figure 6.8 Digital sensors

- An analog sensor is a sensor which transforms a variable physical amount into a signal which the control system can deal with it, either a current or voltage. The physical amounts are like distance, temperature, humidity, speed and pressure among others. There is a general class of sensor for each of these. Some sensors incorporate amounts, such as humidity and temperature or speed and distance into a single device giving two signals [70].

Figure 6.9 Analog sensors

- There are some general classes of signals created by these instruments. For temperature sensing, the instruments themselves generate either millivolt-range signals in the state of thermocouples, or variable resistances in the state of Resistance Temperature Detectors (RTDs) which are generally a better sensing device when we can utilize them due to their higher repeatability and precision.

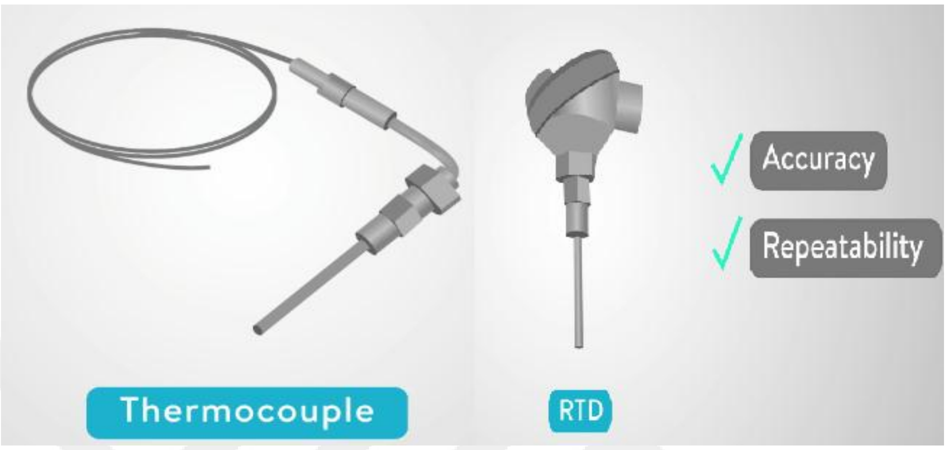


Figure 6.10 Temperature sensors

- PLCs have cards which are patterned to deal with both of these types of instruments. The remainder of the signal classes are transformed locally into a more generally understood shape of signal, either current or voltage before being tied to the control system. If the temperature signals must travel very long to the control system, we commonly transform them such as this also.
- Today, the most commonly utilized norm is 4-20 mA signal due to noise impregnability and other features, and each kind of analog sensor, which is previously mentioned, can generally be bought in that kind of output.

These sensors and a few others, with their signals which are addressed by software and hardware, control the manufacturing operations of the world [70].

6.1.2.1 *Suggested Sensors in Our Work*

Because of the big number of signals that are needed to be measured and dealed with them. For that, it had to be used transducers which convert the measured values to an other values that can be understood by SCADA systems.

The transducer generates an output signal that its value has a relation with the scaled value. The amount of the input signal may be flow, temperature, vibration, speed etc. The value of the output signal may be an air pressure, current or voltage [76].

The most important sensors that can be used in our system:

1. Current and Voltage Transducer.
2. Anemometer.
3. Pyranometer.
4. Ambient Temperature Sensor.
5. Level Water Sensor.

1. Current and Voltage Transducers

Transducers transform AC, DC and distorted currents or voltages into norm analog signals [78].

Some features of the suggested current transducer:

- Electrical isolation of input and output signals.
- Contact-free measurement of live conductors .
- Large input signal opening.

The Table 6.2 contains some types of current transducers which we can deal with them in our study.

Figure 6.11 Current transducer 4-20 mA output [78]

Table 6.2 Some types of current transducers which its output 4-20 mA

Input signal	Output signal
0-100 A	4-20 mA
0-200 A	4-20 mA
0-300 A	4-20 mA
0-400 A	4-20 mA
0-500 A	4-20 mA
0-600 A	4-20 mA

Figure 6.12 Voltage transducer 0-15 V DC input to 0-10 V DC output [77]

2. Anemometer with analog output 4÷20 mA

The wind speed is measured by the most popular device which is called Anemometer. This measurements are achieved at regions where the weather monitoring occurs routinely like wind farms and airports. Experience proved that this device is considered reliable and strong and can run without observation for years and it is simple to set up due to it is omni-directional [71].

The electrical output signal consists of a sequential group of pulses with hesitances which are commensurate to the velocity of the rotor set on the sensor transducer.

Table 6.3 The main features of suggested anemometer [72]

Common features	
Wind speed	
Measuring range	0÷50 m/s
Threshold	0.36 m/s
Resolution	0.06 m/s
Electrical features	
Output	4÷20 mA
Power supply	10÷30 V AC/DC
Power consumption	0.5 W
Microprocessor	PIC 18F2620

Figure 6.13 Anemometer

3. Pyranometer with analog output 4÷20 mA

The quantity of beamy power (electromagnetic radiation from the sun) on a planed surface is called Global irradiance . It is necessary to measure irradiance for finding the amount of power that the solar project can be take from the sun. The irradiance of sun can be measured from all directions in watts per meter square W/m^2 by the device which is called Pyranometer [73,75].

Figure 6.14 Pyranometer

Equation to Convert Measured Output to Solar Radiation [74]:

Solar radiation = (sensor output – 4 mA) * conversion factor

For example for full sunlight:

Solar radiation= (18.1 mA - 4.0 mA) * 78 W/m^2 per mA = 1100 W/m^2.

Table 6.4 The main features of suggested Pyranometer [74]

Common features	
Solar radiation	
Measuring range	0÷1100 or 1500 W/m^2
Sensitivity	78 w/m^2 per mA
Electrical features	
Output	4÷20 mA
Output offset	4 mA
Power supply	5-36 V DC

4. Ambient Temperature Sensor with analog Output 4-20 mA

This sensor is used to know the outdoor temperature and according to the values from sensor is implemented some instruction depending on the program in the controller.

Figure 6.15 Ambient temperature sensor [80,81]

Table 6.5 The main features of suggested ambient temperature sensor [80,81]

Common features	
Measuring range	-40 to +90 °C
Output	4÷20 mA
Power supply	12 to 28 V DC

5. Level Water Sensor

Water Level Sensor supplies extremely precise water level measures for a spacious diversity of implementations, inclusive those in severe milieu.

A solid state submersible pressure transducer is existed inside of each of the water level sensors which its house consist of a stainless steel with 13/16 inch diameter [79].

Figure 6.16 Water level sensor

Table 6.6 The main features of a water level sensor [79]

Common features	
Measuring range (According to type)	0-3, 0-15, 0-30, 0-60, 0-120, 0-250, 0-500 ft
Output	4÷20 mA
Power supply	8 to 36 V DC
Current Draw	Same as sensor output

6.2 Software Programs

6.2.1 PLC Programs Package

PLC programs package is a programming software solution for solving control problems. Its automation tool is the PLC programming software. The PLC programming software is the basic tool in PLC programs package. The whole program of a central processing unit (CPU) is composed of the user program and the operating system. The operating system is cannot be changed because it is a fixed part of the program , but the user program is not fixed, it can be changed. The programming languages in PLC programs package are Statement list (STL), Ladder (LAD), Function block (FBD), Istructions lists (ILs) and Squential functions charts (SFC). The program (user program) was written by Ladder language in this thesis. PLC Simulator user interface gives the capability to the operator to test and run offline programs without additional hardware.

The simulator and the PLC programming software are functioning in integrated way and are both interfaced into the model milieu for that the model can be controlled [58,62].

The PLC programs package supplies a series of tools within the software that are encompassed in PLC programming software. These tools are, which often exists in the good packages, like [58]:

1. Symbol Editor.
2. Diagnosing Hardware.
3. Programming Languages.
4. Hardware Configuration.
5. Network Configuration.

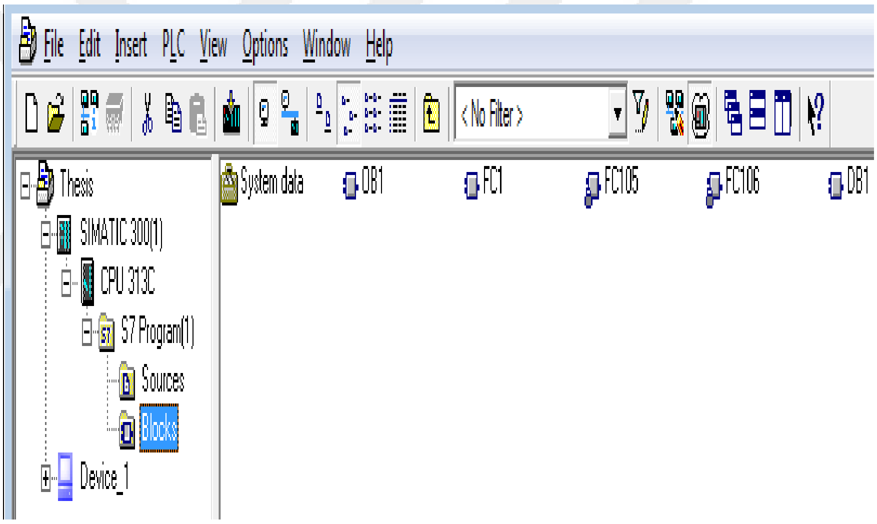


Figure 6.17 The main interface in one of PLC programming software

6.2.1.1 *Symbol Editor*

The Symbol Editor helps the user to manage all the participated symbols. The main tasks of this tool are:

- Putting comments and symbolic names for the operation signals (outputs/inputs), blocks and bit memory.
- Sort tasks.
- Export/Import from/to other Windows programs.

There is a relation among this tool and other tools, for example, The symbols table which is generated by this tool is available to all the other tools, so any small change on the information of a symbol is modulated automatically by all other tools. In Some PLC programming softwares, the programming interface and Symbol editor are in the same interface.

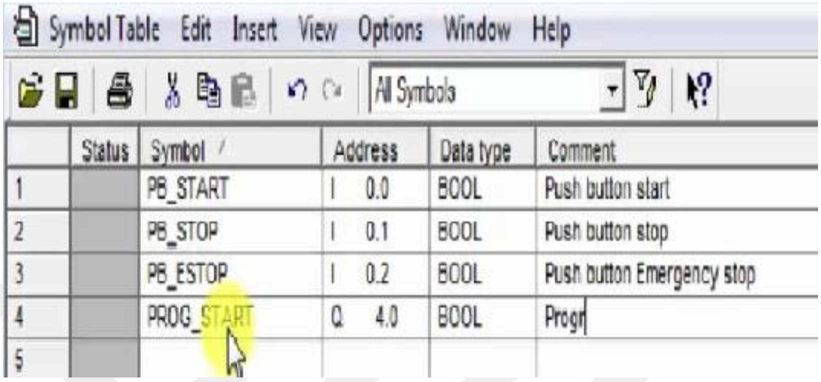


Figure 6.18 Interface of symbol editor in one of PLC programming softwares [88]

6.2.1.2 *Programming Languages*

Function Block Diagram, Instruction Lists, Ladder Logic, Squential Function Charts and Structured Text are the programming languages for PLC programming software which are an integral part of the PLC programs package.

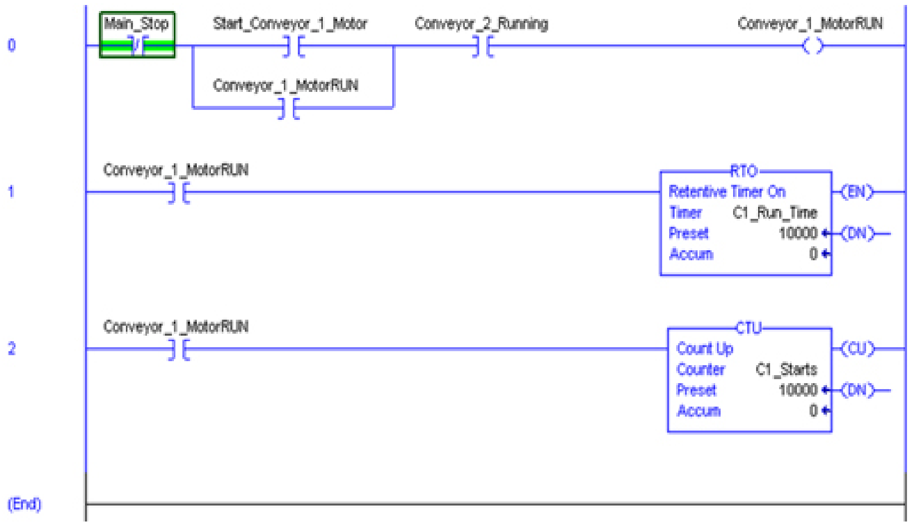


Figure 6.19 Interface of programming languages in one of PLC programming software [89]

6.2.1.3 *Hardware Configuration*

This tool is utilized to select and configure parameters to the hardware of an automation system. The next tasks are existent:

- Selecting racks from an electronic catalog and regulating the chosen modules in the selected slots in the racks for configuring the logic controller.
- Configuring the distributed I/O is identical to the configuration of the central I/O.
- When parameters are being selected to the CPU, properties can be set like scan cycle time monitoring guided and startup behavior via menus. Multicomputing is supported. The entered data are saved in system information blocks.
- When the parameters are being selecting to the modules, all the parameters can be set by utilizing dialog boxes. The settings for utilizing DIP switches are not available. Selecting the parameters to the modules is made automatically when CPU startup. That indicates, for instance, that a module can be replaced without selecting new parameters.
- Selecting parameters to communications processors (CPs) and function modules (FMs) can be done by the Hardware Configuration tool in punctually the same path like the other modules.

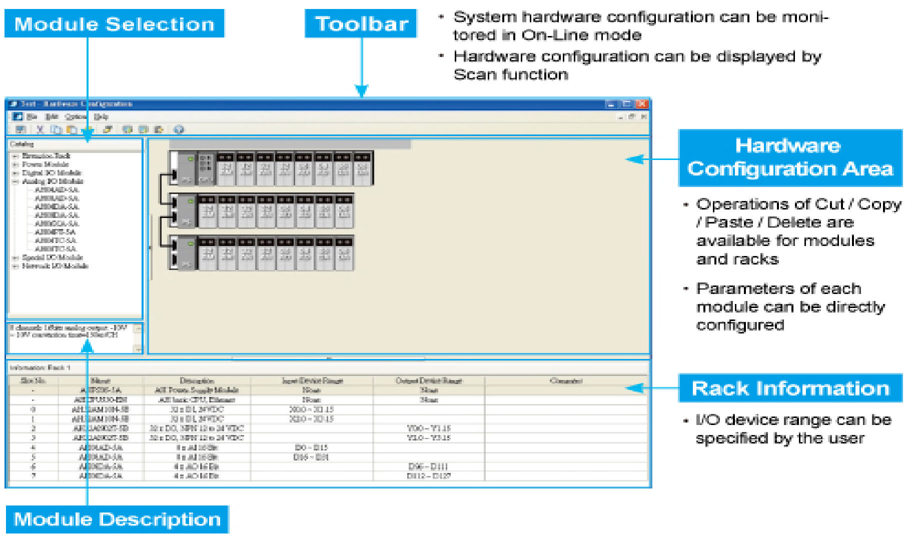


Figure 6.20 The interface of hardware configuration in one of PLC programming software [90]

6.2.1.4 *Diagnosing Hardware*

An overview of the case of the programmable controller give these tool. This tool is not sometimes existed in some softwares. An overview can offer symbols to clarify whether each module has a error or not. A double-click on the faulty module shows accurate data about the error. The range of this data relies on the individual module:

- Show general data about the case of the module (for instance, faulty) and the module.
- Show the module errors (for instance, channel error) for DP slaves and the central I/O.
- Show messages from the diagnostic buffer.

For CPUs the next extra data is showed:

- Reasons of error in the addressing of a client program.
- Show the cycle period (of the shortest, longest and last cycle).
- Communication interface and load possibilities.
- Show performance information (blocks, counters, number of possible inputs/outputs, timers and bit memory)

6.2.1.5 *Network Configuration*

Using Network configuration time-driven cyclic data transfer via the communication interface is possible where you:

- Choose the telecommunication points
- Enter the data target and data source in a table; all blocks (SDBs) to be downloaded are created automatically and fully downloaded to all CPUs automatically.

Event-driven data transfer is also possible where you:

- Regulate the communication connections.
- Choose the function blocks or telecommunication from the integrated block library
- Specify parameters to the function blocks or chosen communication in your selected programming language.

6.2.2 Human Machine Interface

Highest transparency is important for the user who functions in an milieu where operations are becoming more complicated, and demands for machine and factory functionality are rising. This transparency is supplied by the Human Machine Interface (HMI).

The HMI system is considered the mediator between operation (machine/plant) and man (operator). The PLC is the factual unit that controls the operation. So, the mediator (interface) is available between the user and HMI software (at the HMI device) and a mediator (interface) is also available between HMI software and the PLC. An HMI system supposes the following duties [63]:

- Operation representation : The operation is represented on the HMI instrument. The screen on the HMI instrument is dynamically updated. This is depended on operation changes.
- User control of the operation: The user can control the operation via the GUI. For instance, the user can reset reference values for start a motor or the controls.
- Showing alarms: Critical operation cases automatically give an alarm, for instance, when the setpoint value is surpassed.
- Archiving alarms and operation values: The HMI system can register operation values and alarms. This feature permits you to register opertion sequences and to recover prior production information.
- Alarms and Operation values registering: The HMI system can generate operation value and alarms reports. For instance,this permits you to print out production information at the end of a shift.
- Machine and operation parameter management: The HMI system can save the parameters of machines and operations in recipes. For instance, you can download these values in one pass from the HMI instrument to the PLC to modify over the product version for process of production.

6.2.2.1 *HMI Program*

HMI program introduces a completely integrated, single-source system for multiple user control and observing functions. With HMI software, you always master the operation and forever stay your units and machinery running. As a simple example of HMI program systems are small touch screens for utilizing at machine level. HMI program systems utilized for observing and controlling production systems exemplify the upper end of the performance spectrum. These contain high-performance server/client plants.

After this introduction, it may be talked about HMI software for future-proof machine-oriented automation connotations with restful and extremely effective engineering. HMI software incorporates the following advantages [63]:

- Direct handling.
- Transparency.
- Elasticity.

When you generate a new or open an existing project in HMI software, the HMI software opens on the screen of your programming computer. There is a window which is utilized to manage the project and to visualize the structure of project.

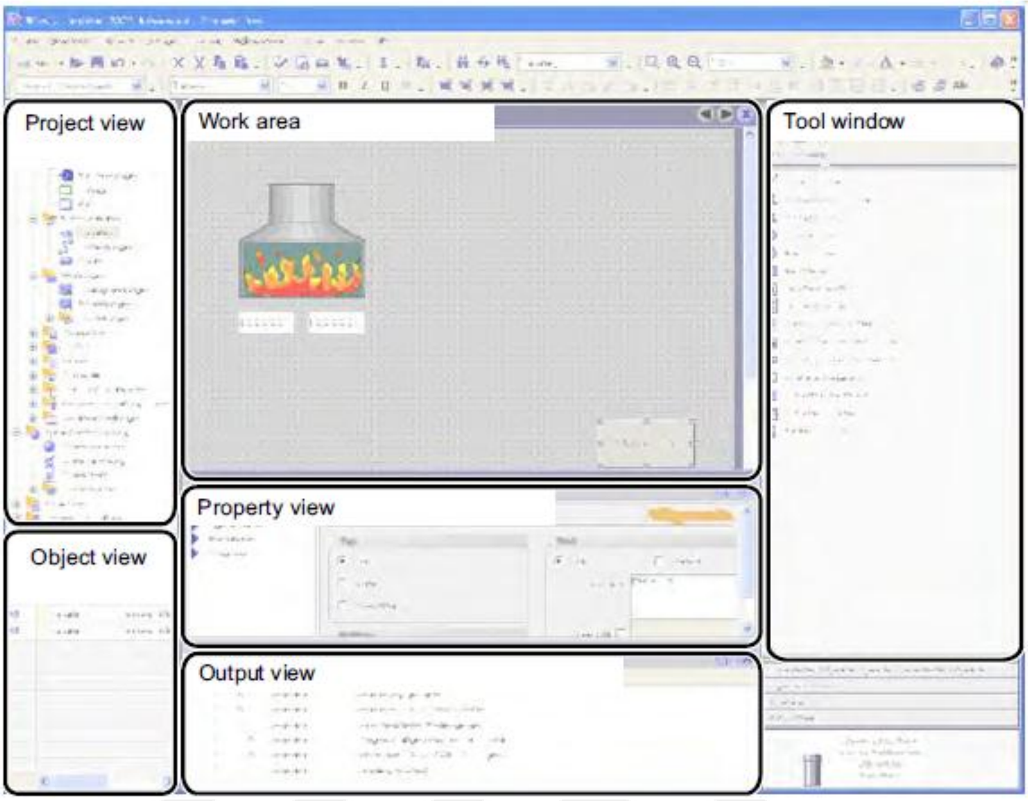


Figure 6.21 The interface of one of the HMI software

HMI software supplies a specific editor for each configuring function. For instance, the GUI of an HMI instrument can be configured in the "Screens" editor or "Discrete Alarms" editor can be utilized to configure alarms.

All project configuration data, which are associated to a project, is saved in the project database.

6.2.2.2 *Automation Concepts with HMI Software*

HMI software backs the configuration of various automation connotations. The next automation connotations can be executed by default utilizing HMI software.

A. Control with one HMI device

An HMI instrument that is straightway tied to the PLC by the operation bus and it is called to as a single-operator system. Single-user systems are generally utilized near from the prossess, but it can also be expanded to run and observe freelance part operations or system parts.

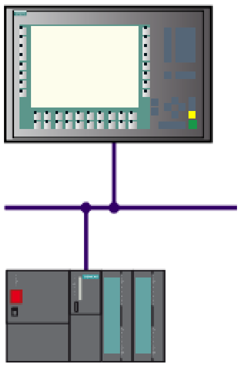


Figure 6.22 Control with one HMI device

B. PLC with several HMI devices

Many HMI instruments are tied to one or more PLCs by a operation bus (e.g. Ethernet or PROFIBUS). These systems are expanded, for instance, in a production line to run the system from many positions.

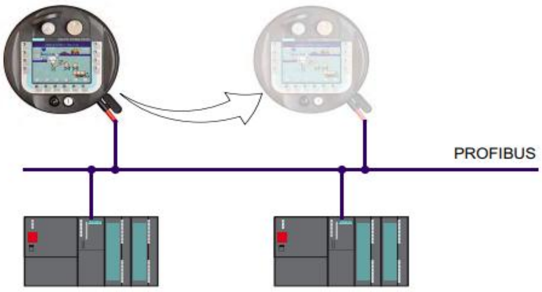


Figure 6.23 PLC with several HMI devices

C. HMI System with centralized functions

An HMI system is tied to a PC by Ethernet. The central PC supposes central tasks, e.g. recipe management. The important recipe data registers are supplied by the vassal HMI system.

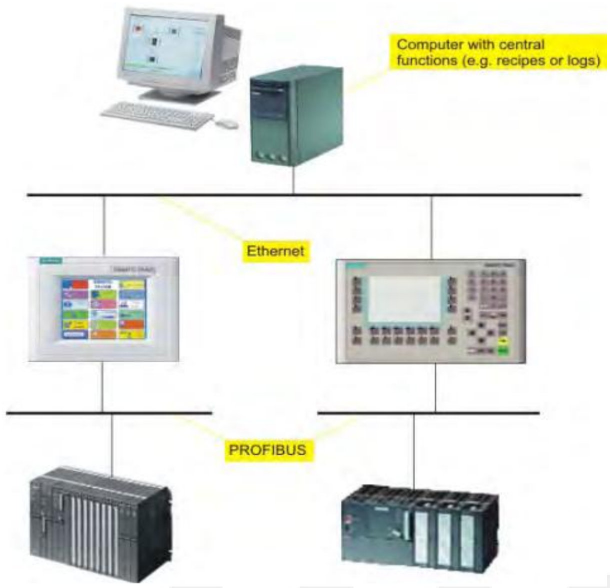


Figure 6.24 HMI system with centralized functions

D. Support for Mobile Units

Mobile units are fundamentally executed in big production systems, long production lines or in conveyor technology, but can also be executed in plants that straightforward visible liaison with the operation is important. The machines are provided with many interfaces that can be tied with them for running these devices, for instance, the Mobile Panel 170.

The service technician or operator can thus function immediatly on location. This qualifies an precise setting up and positioning, e.g. through the startup status. In the state of servicing, mobile units guarantee shorter downtimes.

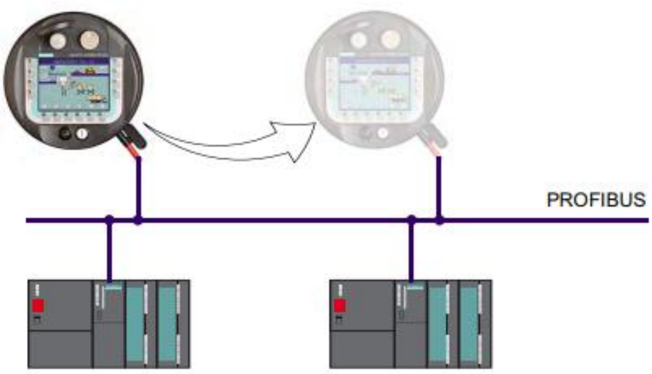


Figure 6.25 Support for mobile units

CHAPTER 7

ASSIGNING POWER SOURCES

7.1 Assigning the Software Program

There are various software packages which can be utilized to simulate clean energy and mixed power systems to supply design solutions, cost effective and optimum size for specific load, demands, environmental constraints and fuel usage. Professional, instructors and engineering students should be conscious for existing these software packages. By learning and reacting to utilize these software packages, students are faced to new technical and non-technical dexterities as ones facing the professional engaged in modernistic manufactures. These knowledge and dexterities make the students are capable to get suitable solutions of clean energy systems and to become familiar with the current clean energy manufacture practice [86].

The trial mode of HOMER software package was utilized in this thesis. This software package can model, simulate and analyze clean energy or mixed power systems which can contain solar/PV panels, wind turbines, micro-turbines, hydropower, batteries, generator, cogeneration, fuel cells and other inputs [86].

In 1993, HOMER was first improved for internal Department of Energy (DOE) which utilized it to know the trade-offs among various power grneration configurations. After a few years from the original design, NREL (National Renewable Energy Laboratory) produced a version which is publically existed for free to support the designers which are interested in clean energy. From that time, HOMER has stayed a free software program that has developed in to a strong software for dealing with both traditional and clean energy technology [82].

HOMER facilitates the function of valuing designs for on-grid and off-grid energy systems. When the energy system is designed, the several decisions must be made about the configuration of the system, like [83]:

The best elements for the system.

The size and number of each element which make the system are most efficacious.

HOMER's sensitivity analysis and optimization algorithms make easier to evaluate the several possible system configurations because the big number of technology choices, difference in costs, and existence of power sources make taking these decisions complex [83].

7.1.1 Using HOMER

The work on HOMER starts after opening the program where select the region of work via specifying latitude and longitude, but if they are unknown, it can be used the map to choose the studied place. After that, the Design button is used for specifying the required system components and entering the necessary information to complete the design operation [84,86].

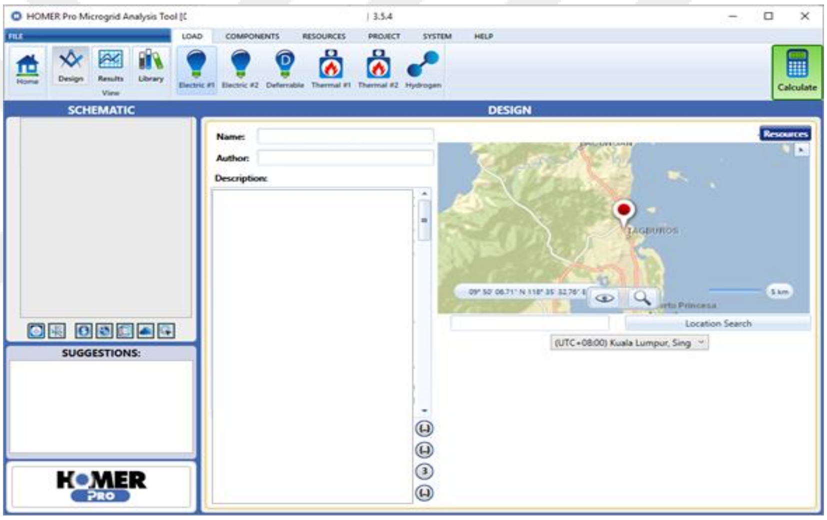


Figure 7.1 Interface of HOMER [83]

After selecting the region, it is specified the load every hour during the day and entered this information from the Load list in design part. This step is considered very important because it will be built upon it the rest of the steps [84,86].

Figure 7.2 Specifying the load in HOMER [84]

Figure 7.3 Details about the load in HOMER [84]

In the next step, the designer select the sources of power which will feed the load. The selection of these components depends on many factors such as the aim of project, budget of project, the available sources and region of work. Then, it will be specifies the resources of power components by resources list like solar irradiance which are taken directly by HOMER from the NASA surface meteorology and solar energy database by entering the GPS coordinates, wind speed are also decided by utilizing the NASA surface meteorology and wind energy database and so that [84,86].

Figure 7.4 List of the power sources in HOMER [84]

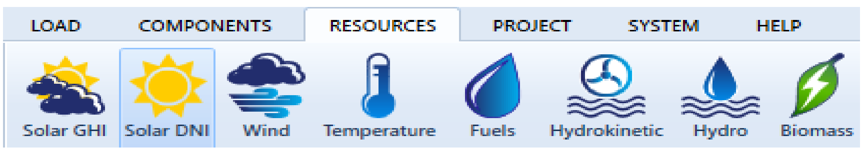


Figure 7.5 List of the resources in HOMER [84]

In the final step, the Calculate button which is utilized in HOMER to benefit from the previous inputs to emulate various system configurations, or incorporations of elements, and gives results which can be viewed as a list of feasible configurations classified by net present cost under the Results button. HOMER also offers simulation results in a wide set of graphs and tables which support the user for comparing configurations and value them on their technical and economic features. In addition the graphs and tables are utilized in presentations and reports [84,86].

Sensitivity		Architecture							Cost			
Gasoline Fuel Price ($/L)	Wind Scaled Average (m/s)	PV (kW)	XL1	Gen (kW)	L16P	Converter (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)
0.40	3.00	2.0		3	12	1	CC	$0.62	$29,283	$850	$18,290
0.40	4.00	1.0	1	3	12	1	CC	$0.61	$28,921	$1,062	$15,190
0.40	5.00	1.0	1	3	12	1	CC	$0.54	$25,575	$803	$15,190
0.40	6.00	1.0	1	3	12	1	LF	$0.48	$22,882	$595	$15,190
0.40	7.00		1	3	12	2	CC	$0.42	$19,958	$852	$8,940

Figure 7.6 Interface of Results in HOMER [84]

7.2 Our Project

7.2.1 Selection of the Region

According to the suggested system, our study is in the town which its name is Darkush,Idlib,Syria [85].

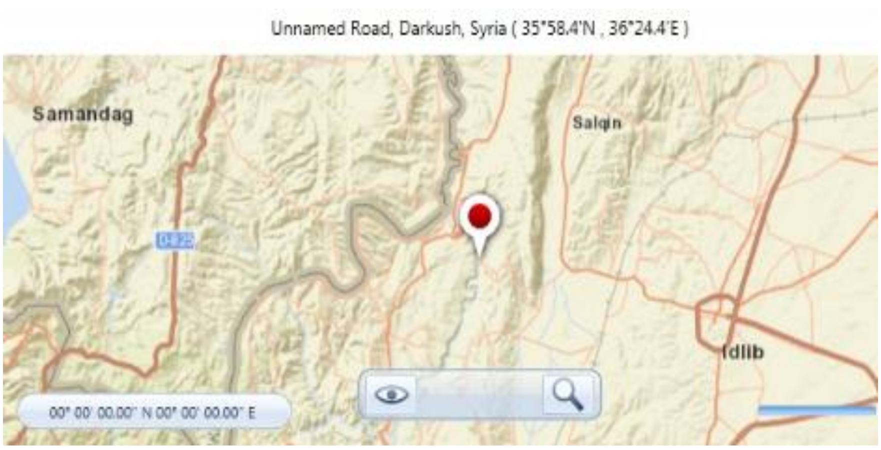


Figure 7.7 Selection of the region for the suggested study by HOMER

7.2.2 Loads Calculations

According to our study, each tank in the camp is supplied with 500 W and initial sevices room which needs 6.250 kW, so each block in camp needs 18.750 kW as a maximum power. The hospital needs 15 kW as a maximum power and the maximum pump power is 10 kW. According to the last values, we can make the loads table which is existed in Table 7.1 [85].

Table 7.1 The loads according to time in this thesis

Hour	Load kW/h
0	42.800
1	42.800
2	42.800
3	42.800
4	42.800
5	42.800
6	65.300
7	65.300
8	65.300
9	65.300
10	65.300
11	55.300
12	55.300
13	55.300
14	67.800
15	67.800
16	100.300
17	100.300
18	100.300
19	100.300
20	100.300
21	100.300
22	100.300
23	100.300

Figure 7.8 The relation between load and time daily each hour

7.2.3 Selection of the Components of the System

In this part, it will be chosen the power generators which use the nature sources to produce the electricity either AC or DC and which will be used in the supposed study step by step. In this study, it is supposed to be used three clean and sustainable power sources which are solar power, wind enegy and hydro power. These sources generate the power via using three generators which are solar panels, wind turbines and hydro turbines.

The first source is solar power which uses the power of sun by means of exploiting the the coming radiation from it. The library of Homer program introduces a collection of solar panels which we can select a suitable panel of it for achieving the required task.

In the suggested system, we can use the type which its main specification are clarified in the Table 7.2 because of its properities.

Table 7.2 The suggested PV panel specifications

Name	Peimar SG310M-BF
Abbreviation	SG310MBF
Temperature coefficient	-0.4
Efficiency (%)	19.1

After choosing the solar panels type, it should be downloaded the data about solar GHI (Global Horizontal Irradiance) resource and temperature resource of the proposed region. The program allows to download this data during the year from one of the international websites like NASA [85].

Table 7.3 Monthly average GHI data and temperature of studied region

Month	Daily radiation kWh/m^2/day	Daily temperature °C
Jan	2.320	7.790
Feb	3.190	8.590
Mar	4.420	11.800
Apr	5.610	16.860
May	6.800	21.010
Jun	7.640	24.850
Jul	7.410	28.310
Aug	6.620	28.230
Sep	5.580	25.190
Oct	4.050	20.640
Nov	2.740	14.360
Dec	2.070	9.400

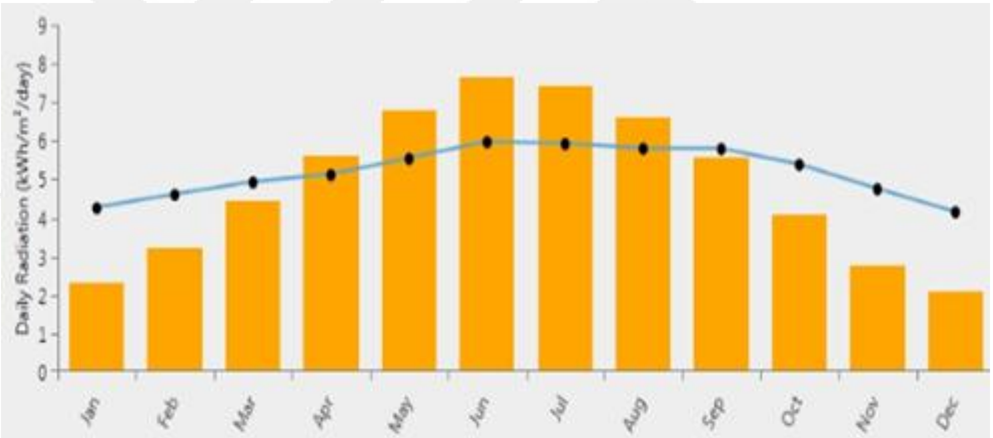


Figure 7.9 Monthly average GHI data

Figure 7.10 Monthly average temperature data

The second source is wind power which converts the moving winds power to an electricity by transforming the mechanical power which results from rotating the blades of turbine to an electrical power. The library of Homer program introduces a collection of wind turbines which we can choose a suitable one of it for performing the required task.

In the suggested system, we can use the type of wind turbine, which its main specification are clarified in the Table 7.4, because of its properities.

Table 7.4 The suggested wind turbine specifications

Name	Gaia-wind 11 kW
Abbreviation	Gaia 11-1
Rated capacity	11 kW

After choosing the wind turbines type, it should be downloaded the data about wind speed of the suggested region. The program permits to download this data during the year from one of the international websites like NASA [85].

Table 7.5 Monthly average wind speed data of the studied region

Month	Wind speed m/s
Jan	5.440
Feb	5.910
Mar	5.750
Apr	5.410
May	5.120
Jun	5.080
Jul	5.330
Aug	5.160
Sep	4.550
Oct	4.540
Nov	4.630
Dec	5.190

Figure 7.11 Monthly average wind speed data

The third used source is hydro power which exploits a flow of river to rotate a hydro turbine for generating the electricity by transforming the mechanical power which results from rotating the blades of turbine to an electrical energy. The library of Homer program introduces a collection of hydro turbines which we can choose a suitable one of it for performing the required function. In the suggested system, we want to try two types of hydro turbine. The first one is Generic Hydro 100 kW (Hyd100) and the second one is Natel FreeJet FJ-7A 49 kW (Natel49) for making the comparison of the system in the two cases to clarify the importance from using the hydro power.

After choosing the hydro turbines type, it should be downloaded the data about flow of the suggested river, but this type of data is entered by hand because the program does not have the data about rivers flow like solar or wind.

Table 7.6 Monthy average stream flow data of the suggested river

Month	Stream flow l/s
Jan	7000
Feb	25000
Mar	25000
Apr	25000
May	7000
Jun	7000
Jul	6500
Aug	6000
Sep	5500
Oct	7000
Nov	5000
Dec	7000

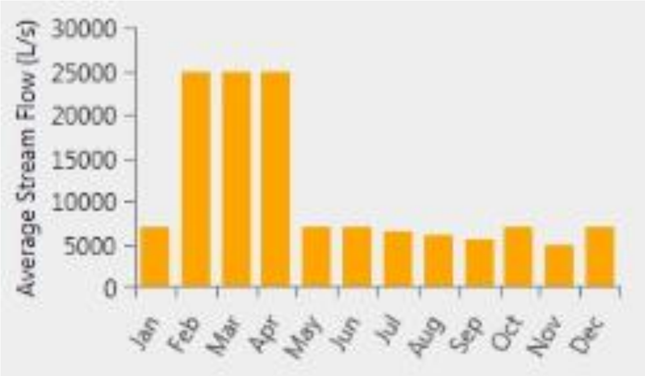


Figure 7.12 Monthy average stream flow data

Finally, the homer allows to use an other electrical components which are needed from the system side to achieve its function. These elements are batteries, inverter or converter, charger controller and generator. The batteries are utlilized for storing the extra power that may be generated from the sustainable and clean power sources and for feeding the load when the main sources of the studied system are not available. There are several types of batteries in the HOMER library which is useful to choose a good type of them for the proposed system. In the suggested system, we can use the battery which its name is the Surrette-S260 and its specifications are illustrated in Table 7.7.

Table 7.7 The suggested battery specifications

Name	Surrette-S260
Abbreviation	Surrs-260
Nominal voltage (V)	12 V
Nominal capacity (kWh)	3.12
Maximum capacity (Ah)	260
Maximum charge current (A)	80
Maximum discharge current (A)	80

The inverter will be used to convert the DC power that is produced by solar panels to AC power for feeding the load and the charger controller is used for charging the batteries. In the suggested system, we can use the converter which can achieve several tasks like MPPT solar controller, battery charger. The name of this converter is Huawei Sun2000-150KTL-50 and its power is 33 KVA.

For the generator , it may be used in the emergency cases when all the clean power sources are not available or in the maintainance cases. In the suggested system, we can use the generator which its name is the Cummins 125 kW 125GGHJ , its abbreviation is Cmns125 and uses the natural gas.

7.2.4 The Results

After choosing the components, the nex step should be the calculation of numbers of components which can achieve the required aim and suggestion the best system for the user.

HOMER can make these calculations automatically, just when the designer push the “Calculate” button. Figure 7.13 illustrates the main components of the proposed system.

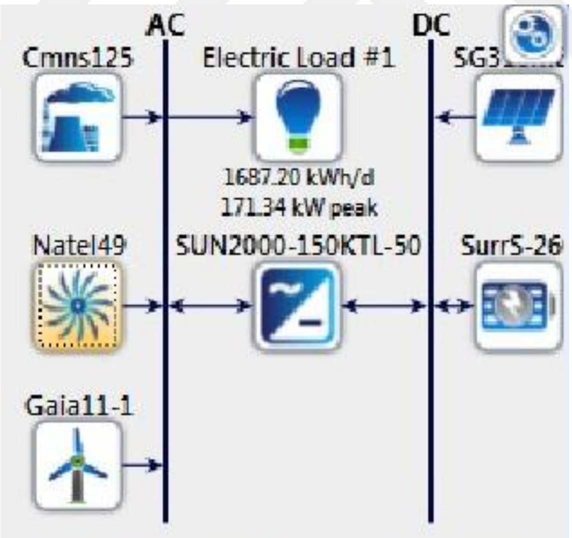


Figure 7.13 The main components of the proposed system

As previously stated, it will be used two types of hydro turbines, which their power are different, to clarify the importance of using the hydro power. The power of the first one is 100 kW and the power of the second one is 49 kW.

1- Hydro turbine 100 kW:

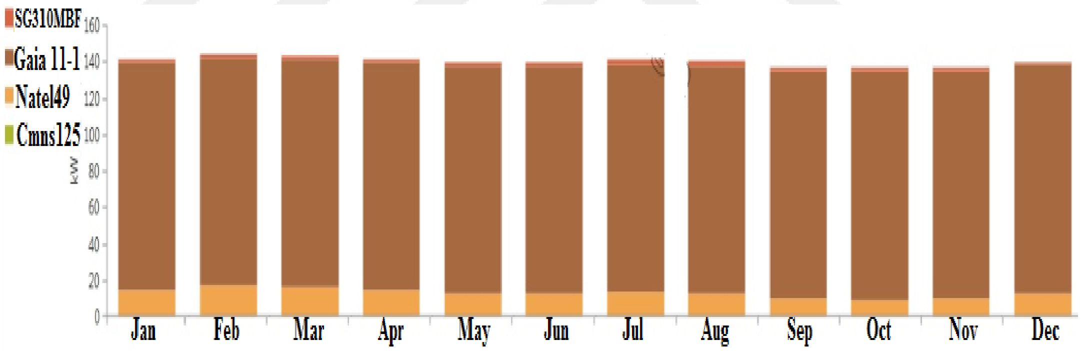
If it is used the 100 kW hydro turbine, the program give us two options for the structure of system. Figure 7.14 illustrates the suggested options, but the second option is suitable for us because it contains all the sources which are used in the studied system.

SG310MBF (kW)	Gaia11-1	Cmns125 (kW)	SurrS-260	Hyd100 (kW)	SUN2000-150KTL-50 (kW)
	5	125	100	98.1	33.0
10.0	5	125	100	98.1	33.0

Figure 7.14 The proposed options from HOMER when it is used 100 kW hydro turbine

The second option contains 10 kW Solar panels, 5 Wind turbines with 11 kW power for each one, 98.1 kW Hydro turbine, 100 batteries with 3.12 kW/h capacity for each one, 33 kW converter and 125 kW generator.

If it is opened the second option, we can get the details and results about the system.



(a)

Production	kWh/yr	%
Peimar SG310MBF	15,843	1.29
Cummins 125kW 125GGHJ	2,025	0.165
Gaia-Wind 11kW 133 1-Phase	111,011	9.07
Hydro	1,095,679	89.5
Total	1,224,559	100

(b)

Figure 7.15 Monthly average electric production

Figure 7.15 a & b illustrates that the proposed system which uses 100 kW hydro turbine in addition to solar, wind, batteries and generator. The hydro power is considered as a main source of 89.5%, then wind power of 9.07%, then solar power of 1.29% and then generator of 0.165%. Figure 7.16 illustrates that the use of batteries is very low.

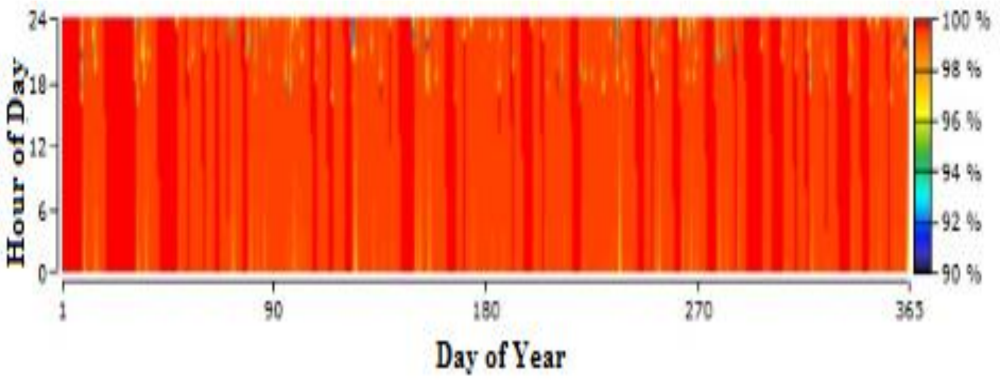


Figure 7.16 State of charge of batteries when 100 kW hydro turbine is used

2- Hydro turbine 49kW:

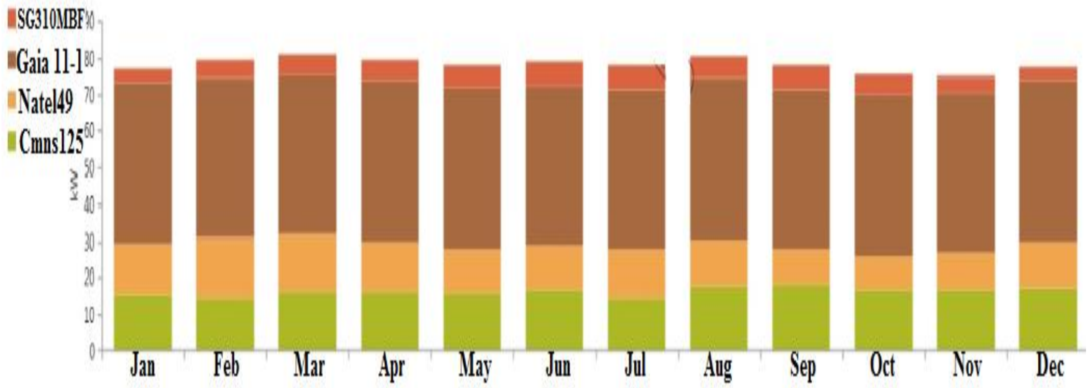
If it is used the 49 kW hydro turbine, the program give us two options for the structure of system. Figure 7.17 illustrate the suggested options, but the first option is proper for us because it contains all the sources which are used in the studied system.

SG310MBF (kW)	Gaia11-1	Cmns125 (kW)	SurrS-260	Natel49 (kW)	SUN2000-150KTL-50 (kW)
30.0	5	125	100	49.0	33.0
	5	125	100	49.0	33.0

Figure 7.17 The proposed options from HOMER when it is used 49 kW hydro turbine

The first option contains 30 kW Solar panels, 5 Wind turbines with 11 kW power for each one, 49 kW Hydro turbine, 100 batteries with 3.12 kW/h capacity for each one, 33 kW converter and 125 kW generator.

If the first option is opened, we can get the details and results about the system.



(a)

Production	kWh/yr	%
Peimar SG310MBF	47,530	6.95
Cummins 125kW 125GGHJ	141,777	20.7
Gaia-Wind 11kW 133 1-Phase	111,011	16.2
Hydro	383,463	56.1
Total	683,782	100

(b)

Figure 7.18 Monthly average electric production

Figure 7.18 a & b illustrates that the proposed system which uses 49 kW hydro turbine in addition to solar, wind, batteries and generator. The hydro power is considered as a main source of 56.1%, then wind power of 16.2%, then solar power of 6.95% and then generator of 20.7%. In addition the use of battery is large. Figure 7.19 illustrates that the state of charge of batteries.

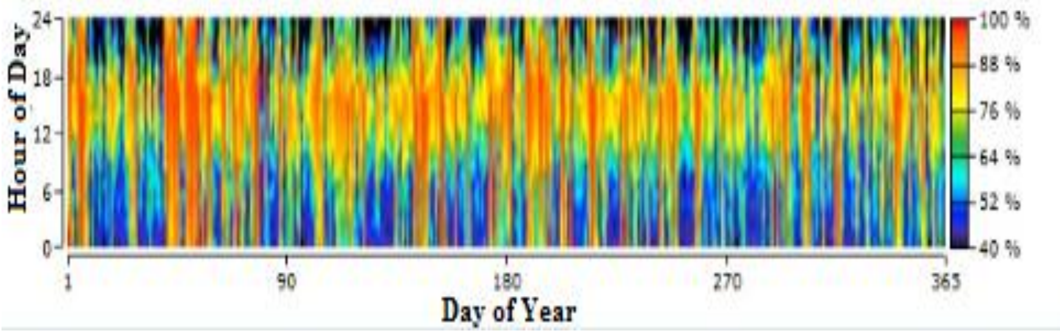


Figure 7.19 State of charge of batteries when 49 kW hydro turbine is used

Finally, if the two previous cases are compared, we can find that decreasing the generated power from hydro power will lead to increase the use of other power sources such as solar by 5.66%, generator by 20.535%, wind by 7.13% and the increase in using the batteries significantly. This increase is considered bad and not good, especially the increase in using the generator which will accompany the emissions which are harmful for environment and increasing the costs of system. In addition the icreasing in using the generator means the increase in consuming the fuel which may be not available in the war regions. Moreover, the increase in using the batteries means that the age of batteries is lower and increases the costs of system.

CHAPTER 8

IMPLEMENTATION AND RESULTS

8.1 The Final Design of Control System-SCADA System

According to the previous chapters where the elements of the system have been selected and their values were determined, the final perception of the system is given in Figure 8.1.

It is taken in a consideration that hydropower is almost always present with varying values according to the abundance of water flow where it is connected with the line AC by converter, then to the load which is the refugee camp in our case. Thus, the generated power of hydro turbine may be not enough, so we should support this source with an other clean and sustainable sources such as solar power and wind power.

In the solar power case, the pyranometer senses the irradiance of sun and the temperature sensor measures the ambient temperature and these values are sent to the controller which is PLC in our case. If these values are within the operating range, for example, if ambient temperature is less than 45 °C and the irradiance of sun is available, the controller sends a command for closing the conductor to connect solar system with AC line via the inverter, then to the load.

In the wind power case, the anemometer senses the existence of wind, then this value is sent to controller which sends a command for connecting the outputs of wind turbines with AC line by the converters, then to the load.

The aim from sensing existence of power sources before using them is increasing the reliable of system and estimating the produced power and increasing the age of system.

The loads (refugee camp) are always fed whereas these loads include four blocks whereas each block contains 25 tents and initial services room, small hospital and a pump of water for filling the water tank of camp. If the dwellers of one of blocks consume more power from that allocated power to their block. The controller separates the power from tents of that block, but the energy will continue to flow to initial services room. When the dwellers of that block stops the extra consumption, the power comes back to tents.

The produced power from sources and the consumed power by loads are measured by current transducers which are connected with the controller for supplying it with these values. The controller takes the received value from transducers and make comparison between the generated power and the consumed power to give the required energy to the loads and exploit the extra power in other operation like charging the battery but if the battery is full, the extra power can be used to operate the heater or other benefit things.

The charging and discharging of the batteries are achieved by charger controller which can be used when there is an extra power or for feeding the loads when the produced power from the clean and sustainable sources are not enough to feed the loads.

The suggested SCADA system superintends on all the previous operations and on the other operations in addition to monitoring the measured values from all proposed sensors for performing the required control and distributing the power optimally to all loads and exploiting the extra power in useful functions without wasting any part from the produced power.

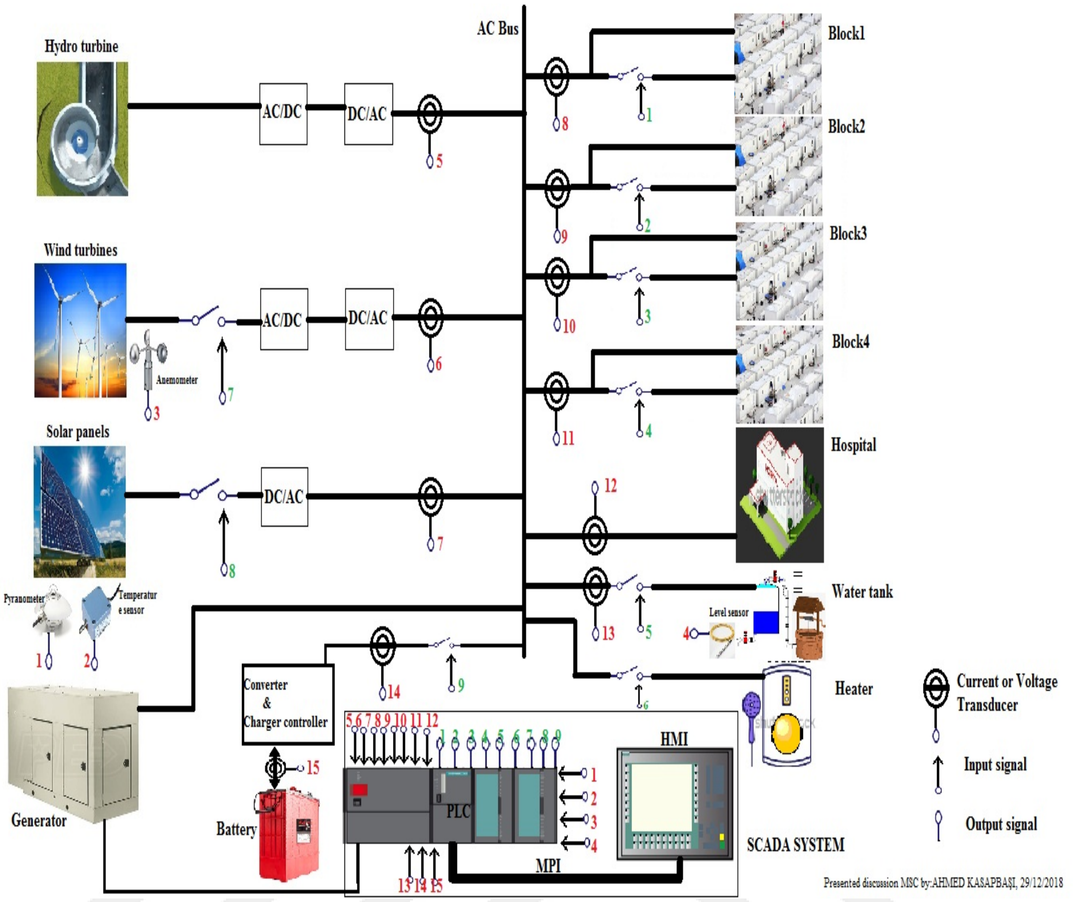


Figure 8.1 Diagram of smart control system (SCADA) for supplying a refugee camp with energy in Darkush region at Idlib,Syria

8.2 The Practical Part

In this part, we use two programs that work togather for achieving the required tasks. The first one is PLC programs package with its PLC programming software which is used for programming the logic controller (PLC) and we depended on the simulator in our work to get the results. The second program is HMI software which is used for programming the HMI.

The PLC will be connected with HMI by communication interface which is a proprietary interface of the programmable logic controller.

- In PLC programming software:

Firstly, we should do the Hardware Configuration which specifies the PLC components that will be used. Figure 8.2 illustrates the general components that may be suggested, to name a few.

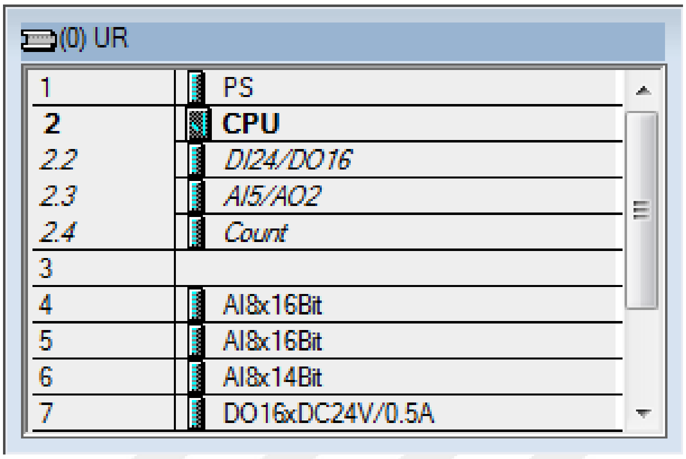


Figure 8.2 The suggested hardware components of PLC

After that, we can start the programming in the programming interface. It will be depended on the Ladder language for achieving this thesis. Figure8.3 illustrates a part from the written program.

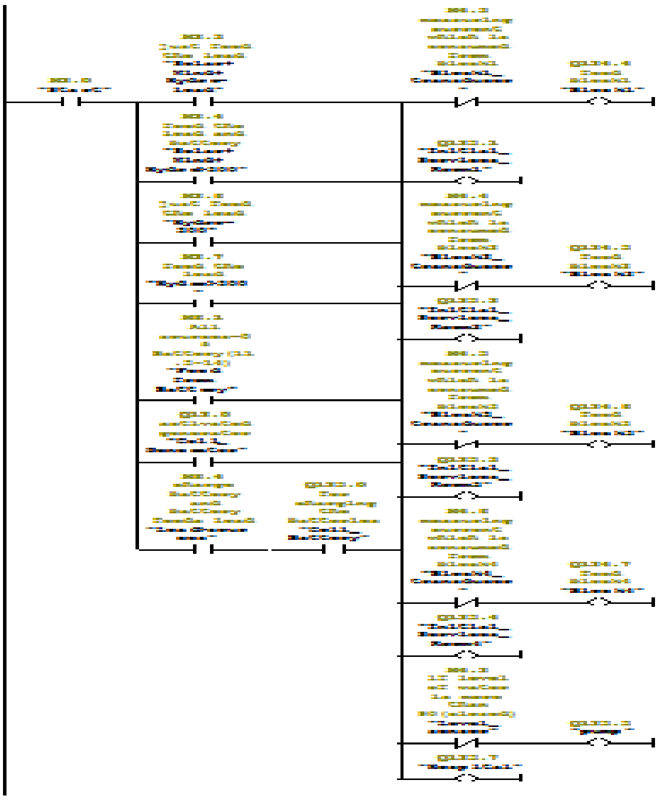


Figure 8.3 One network of the written program

After programming the PLC, we can test the program by using the emulator. Figure 8.4 illustrates generally the interface of the emulator in PLC programming software.

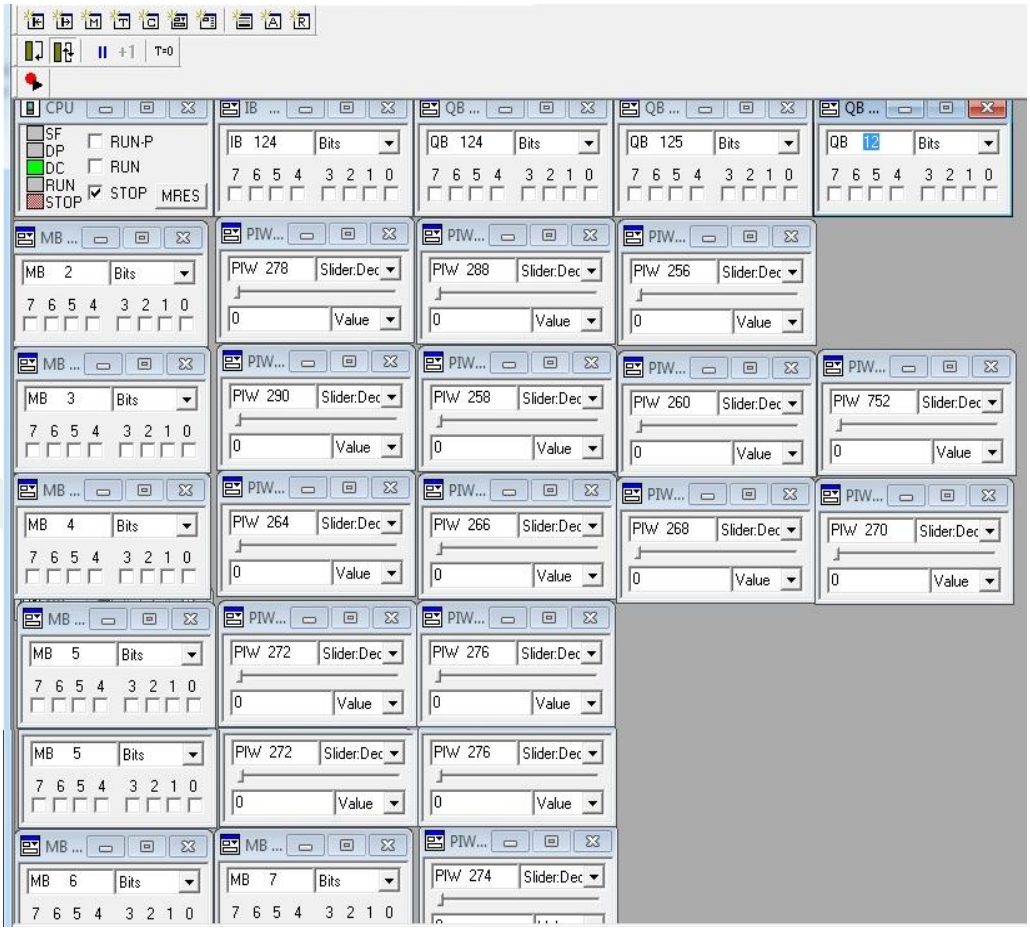


Figure 8.4 The suggested emulator in PLC programs package

Now, we should program the HMI by HMI software which is integrated with PLC programming software to get the final project which was suggested during this study. We can run all the previous components together to simulate and test our project before applying in reality.

Figure 8.5 illustrates the main interface in SCADA system-HMI interface. We can use this screen to enter to other screens like tank screen which is designed for controlling and monitoring the water level of tank, Figure 8.6 illustrates the interface of tank control. The control system senses the level of water by level sensor, thus it can control with running and stopping the pump. This way works to save power, when the pump run in case of need. Trend screen which introduces to user possibility of monitoring the produced and consumed energy graphically.

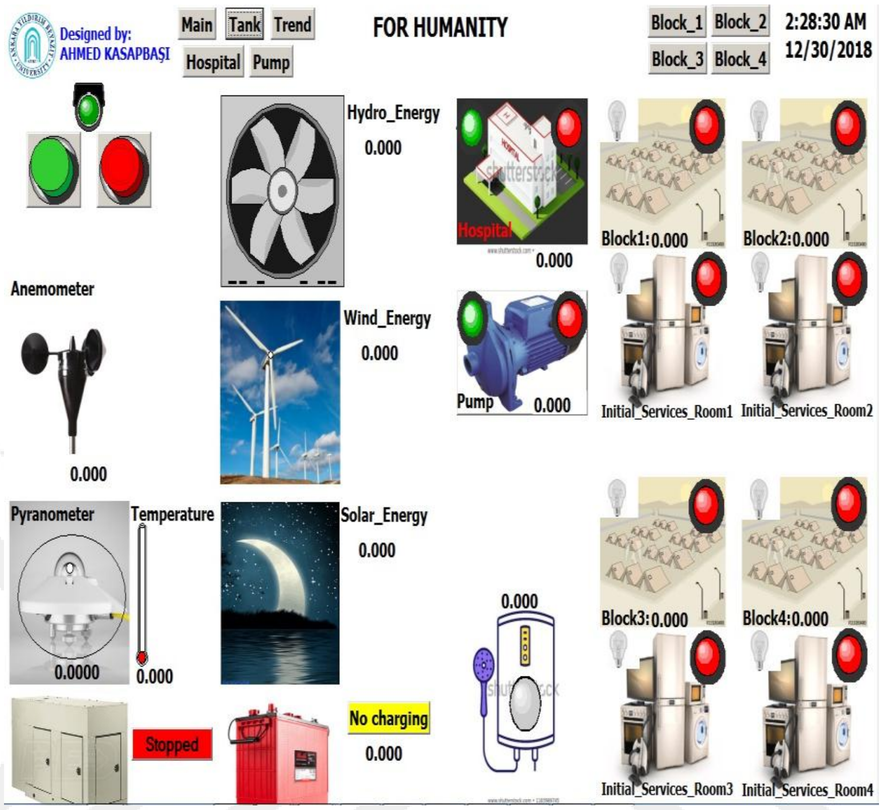


Figure 8.5 The main interface in suggested SCADA system-HMI interface

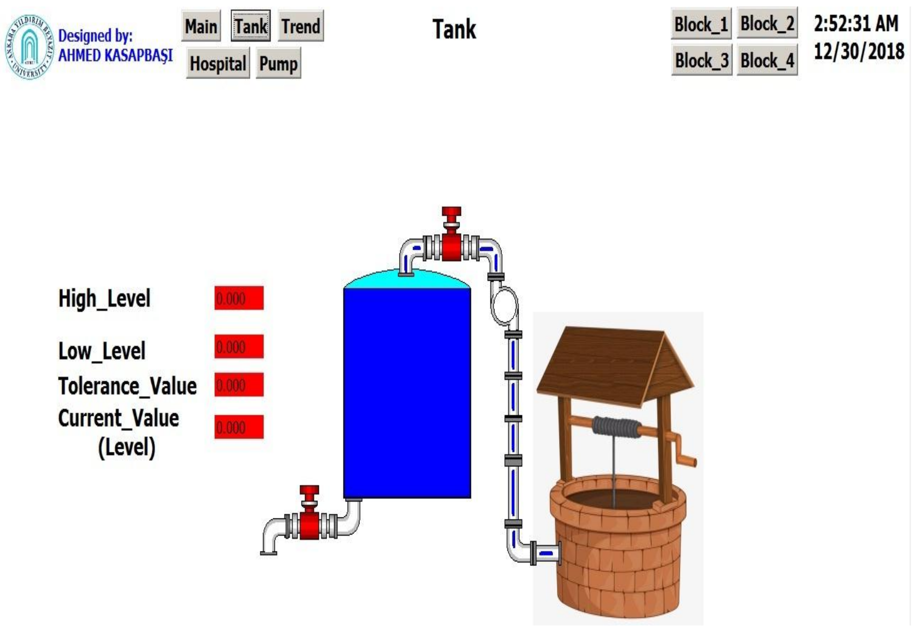


Figure 8.6 The tank interface in designed SCADA system

Table 8.1 The studied general cases

The Studied General States	Battery	State	state.no.
Generated Power = Required Power	Not important	Just feed the load	1
Generated Power < Required Power	Batteries<11.5 V Not charged	Charge the battery from sources and feed load from generator until voltage of battery become more than 11.5 V, at that time the sources will charge the battery and battery will feed the load	2
Generated Power < Required Power	Batteries>11.5 V Need a charge	The sources will charge the battery and battery will feed the load.	3
Generated Power > Required Power	Batteries<15 V Need a charge	Sources feed the loads and extra power will be used to charge the battery.	4
Generated Power > Required Power	Batteries>15 V Charged	Sources feed the loads and extra power will be used to charge the heater.	5

Table 8.1 illustrates the general cases of our studies. The generated power represents the produced energy from all power sources each one separately or combined, so sometimes some sources are not available, for example the sun are not existed at night or the wind does not blow in summer or sometimes all the sources works together. According to that, the system works to use the existed source and exploit the clean power at their existent time.

Here the role of the controller appears that will senses all power sources to specify which one is working and collect all the generated power from the sources via sensors to compare their values with the required power from the load where it takes in a consideration a state of charge of batteries. Thus, the low voltage cut-off of batteries is considered 11.5 V and if the voltage of batteries is less than 15 V that means the batteries need charge and if the voltage of batteries are more that 15 V the batteries are full and does not need a charge.

The first state means that if the generated power equals the needed power, the produced power will be used just for feeding the loads.

The second state means that the generated power is less than the required power and the batteries are not charged. At that time, the batteries will be charged from sources and the loads will be fed from generator until the voltage of batteries becomes more than 11.5 V, at that time the sources will charge the battery and battery will feed the load and this state represents the third state.

The fourth and fifth state occurs when the generated power is more than the required power, but in the fourth state, the batteries need a charge. For that the sources feed the loads and the extra power will be used to charge the battery. On the contrary, in the fifth state, the batteries do not need a charge and the extra power will be used to operate the heaters or in an other useful works.

There are a lot of prospective cases that can be dealed with them by system according to the existent source for that we will discuss some critical cases to prove the effective of the system.

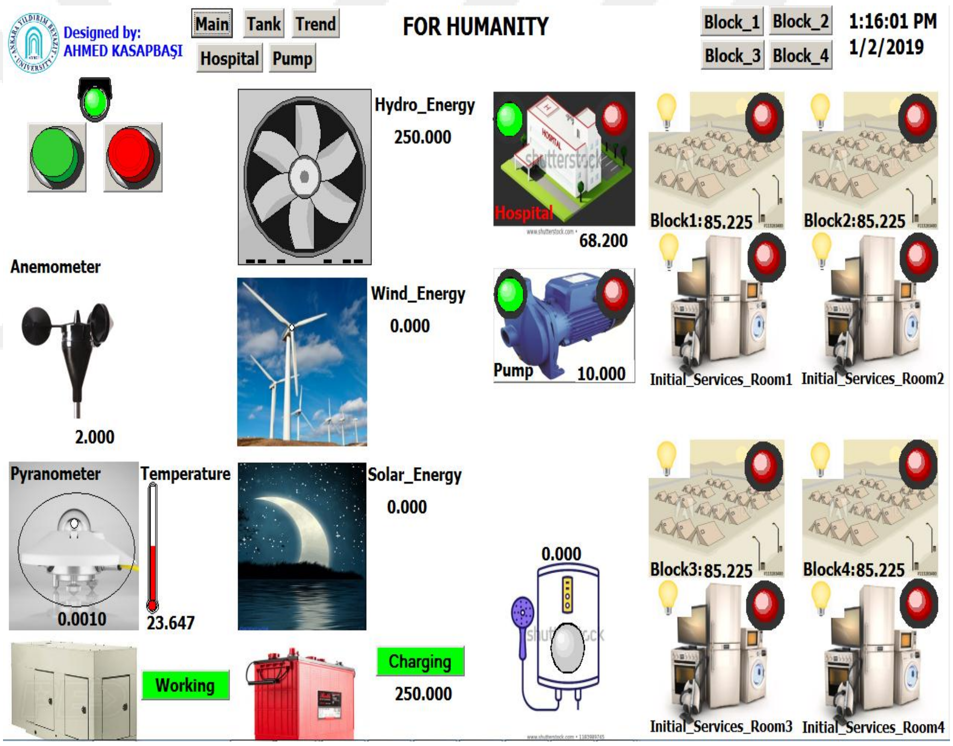


Figure 8.7 State 2 from the Table 8.1

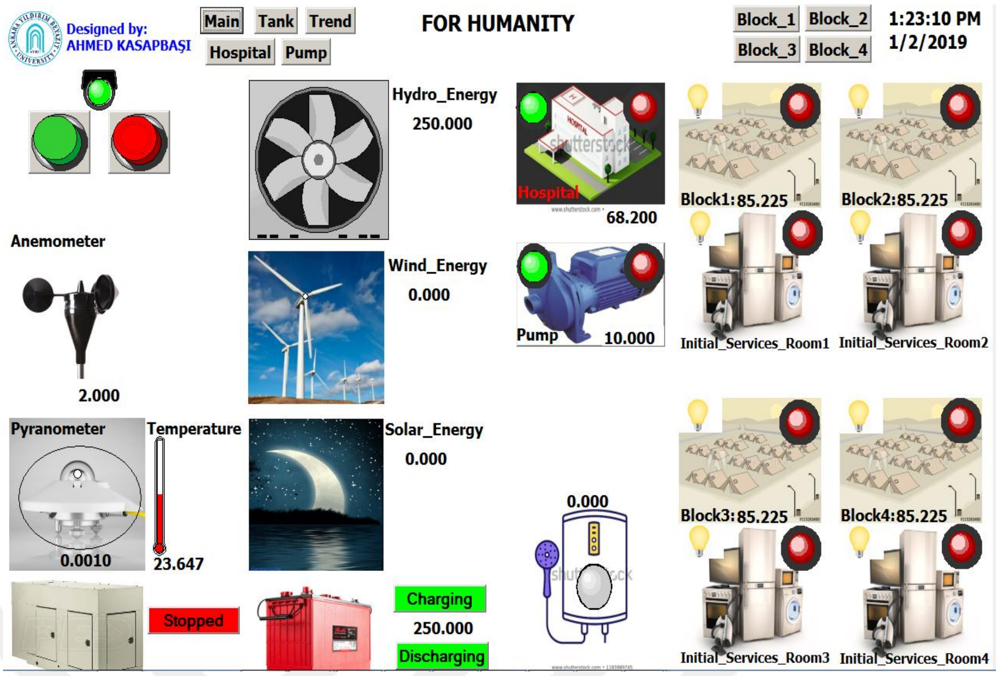


Figure 8.8 State 3 from the Table 8.1

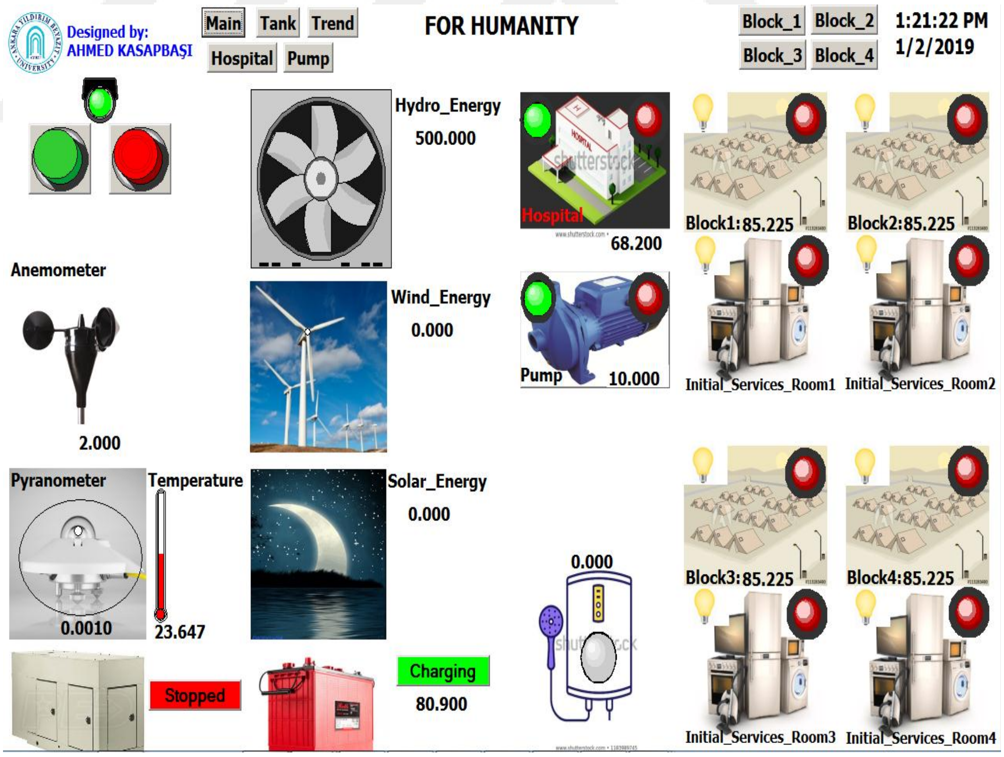


Figure 8.9 State 4 from the Table 8.1

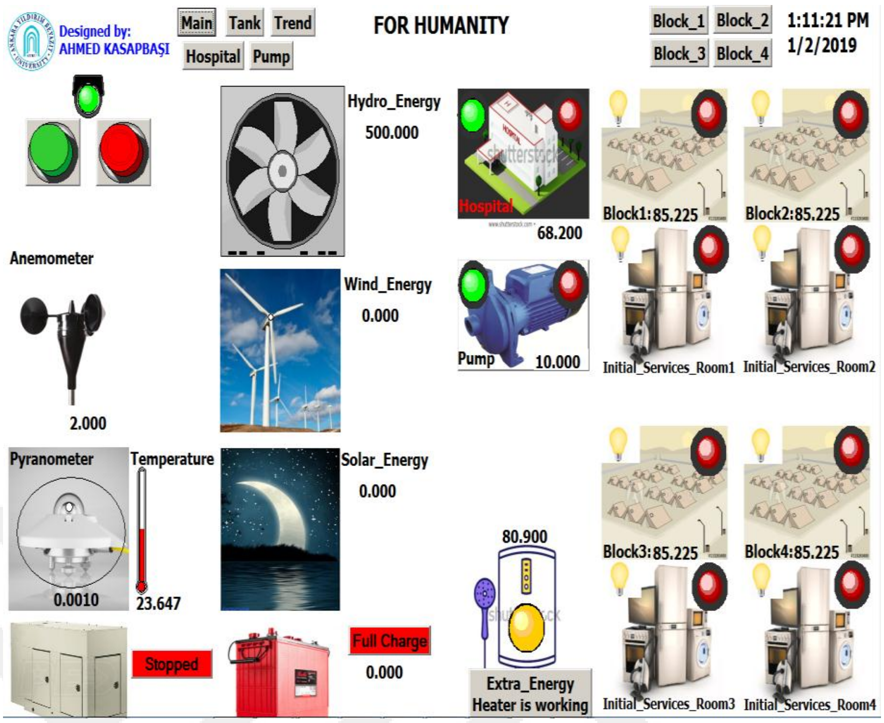


Figure 8.10 State 5 from the Table 8.1

1. **Case**: The hydro power is just available at the maximum value and the other sources are zero and load is at the maximum value.

Table 8.2 The hydro is maximum and other sources are zero and load is maximum

Hydro	Wind	Solar	Sum	Load	Battery	Results
110 kW	0	0	110 kW	100.3 kW	Less than 15 V	State 4
110 kW	0	0	110 kW	100.3 kW	More than 15 V	State 5
55 kW	0	0	55 kW	100.3 kW	Less than 11.5 V	State 2
55 kW	0	0	55 kW	100.3 kW	More than 11.5 V	State 3

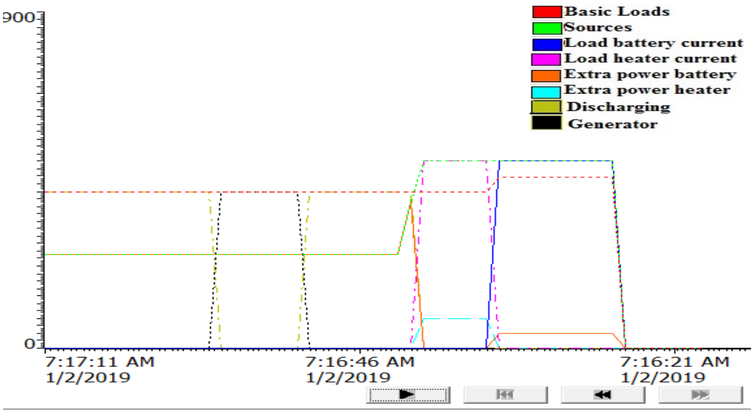


Figure 8.11 1. Case: The hydro is maximum and other sources are zero and load is maximum

2. **Case**: All sources are available, the hydro is available at minimum value and other sources are available at different values and load is maximum.

Table 8.3 The hydro is available at minimum value and other sources are available at different values

Hydro	Wind	Solar	Sum	Load	Battery	Results
55 kW	55 kW	10 kW	120 kW	100.3 kW	Less than 15 V	State 4
55 kW	55 kW	10 kW	120 kW	100.3 kW	More than 15 V	State 5
55 kW	27.5 kW	5 kW	87.5 kW	100.3 kW	Less than 11.5 V	State 2
55 kW	27.5 kW	5 kW	87.5 kW	100.3 kW	More than 11.5 V	State 3

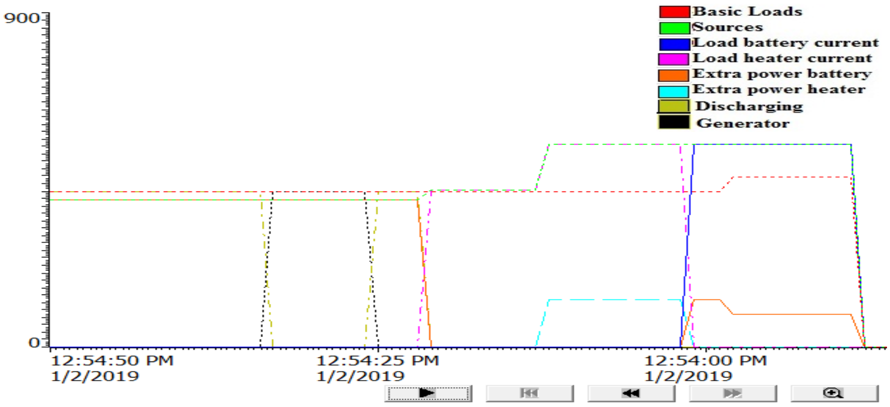


Figure 8.12 2. Case: The hydro is available at minimum value and other sources are available at different values.

3. **Case**: The hydro and wind powers are available and load is maximum.

Table 8.4 The hydro and wind powers are available and load is maximum

Hydro	Wind	Solar	Sum	Load	Battery	Results
55 kW	55 kW	0	110 kW	100.3 kW	Less than 15 V	State 4
55 kW	55 kW	0	110 kW	100.3 kW	More than 15 V	State 5
55 kW	27.5 kW	0	82.5 kW	100.3 kW	Less than 11.5 V	State 2
55 kW	27.5 kW	0	82.5 kW	100.3 kW	More than 11.5 V	State 3

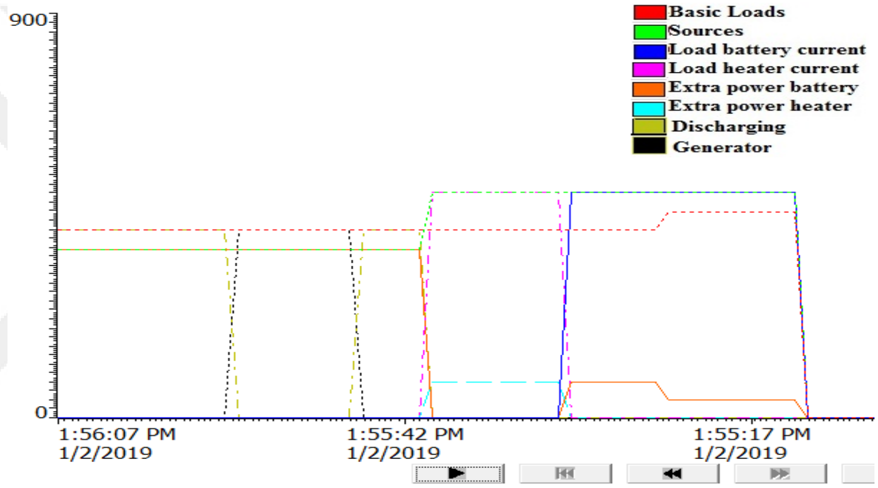


Figure 8.13 3. Case: The hydro and wind powers are available and load is maximum

4. **Case**: The hydro and solar powers are available and load is changeable.

Table 8.5 The hydro and solar powers are available and load is changeable

Hydro	Wind	Solar	Sum	Load	Battery	Results
55 kW	0	10 kW	65 kW	55.3 kW	Less than 15 V	State 4
55 kW	0	10 kW	65 kW	55.3 kW	More than 15 V	State 5
55 kW	0	5 kW	60 kW	65.3 kW	Less than 11.5 V	State 2
55 kW	0	5 kW	60 kW	65.3 kW	More than 11.5 V	State 3

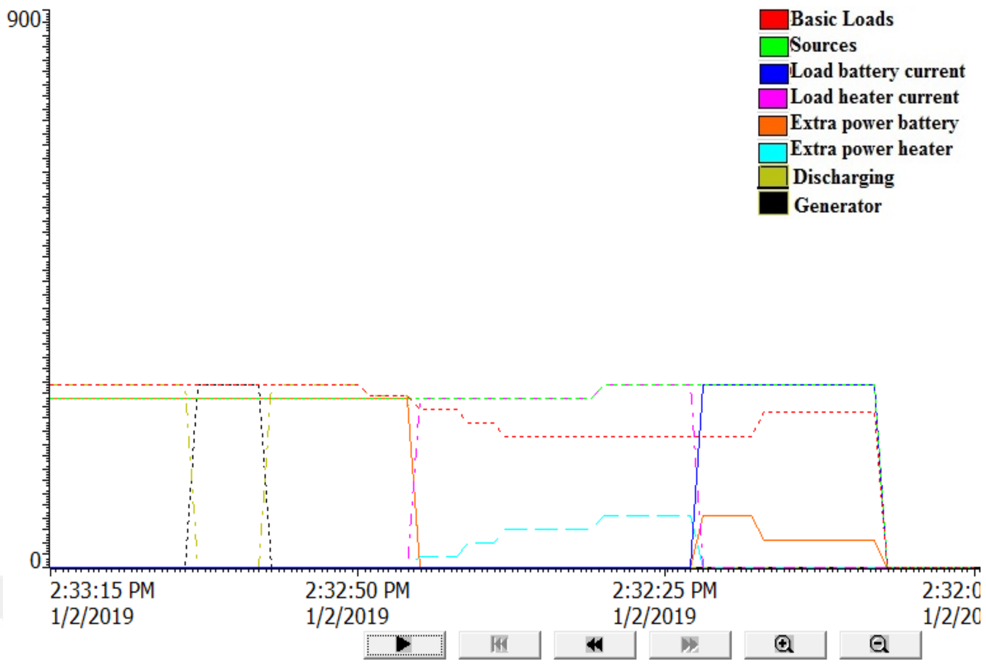


Figure 8.14 4. Case: The hydro and solar powers are available and load is changeable

➢ **Other variety cases**

A. The load is maximum and hydro power is minimum and battery charged: we can write the following table.

Table 8.6 The load is maximum & hydro power is minimum

Hydro	Wind	Solar	Sum	Load	Battery	Results
55 kW	0	0	55 kW	100.3 kW	Charged	State 3
55 kW	27.5 kW	5 kW	87.5 kW	100.3 kW	Charged	State 3
55 kW	55 kW	10 kW	120 kW	100.3 kW	Charged	State 5

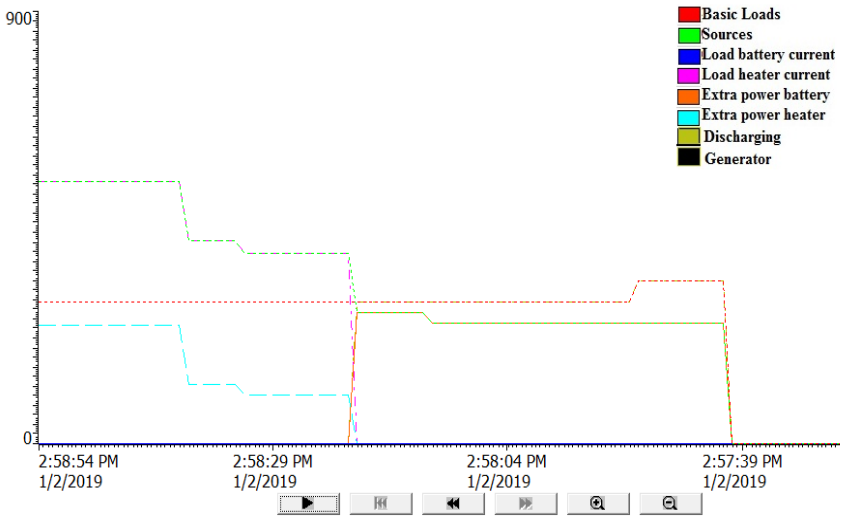


Figure 8.15 The prospected cases when the load_maximum & hydropower_minimum

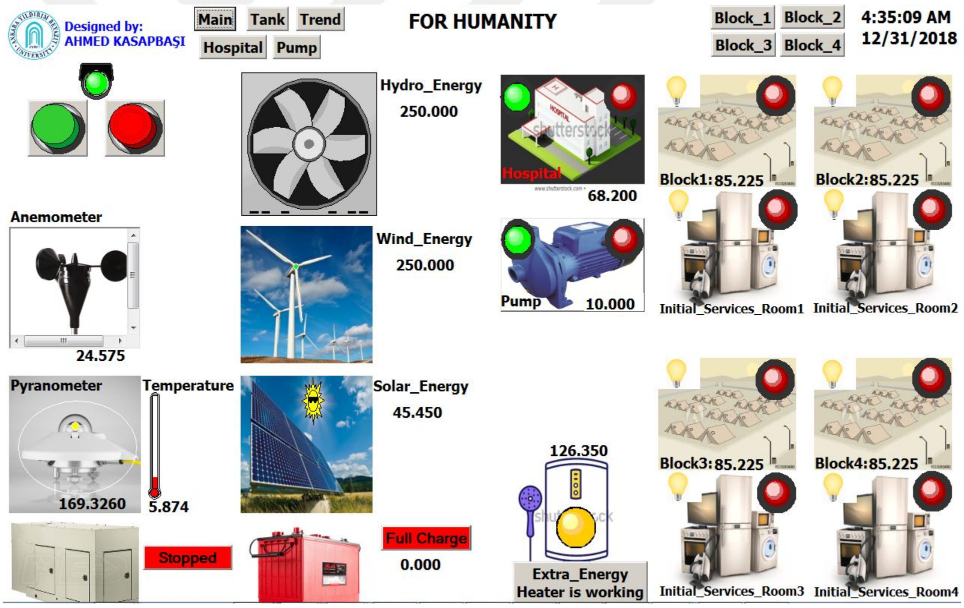


Figure 8.16 HMI-The SCADA interface when load_maximum & hydro_minimum & wind_max & solar_max

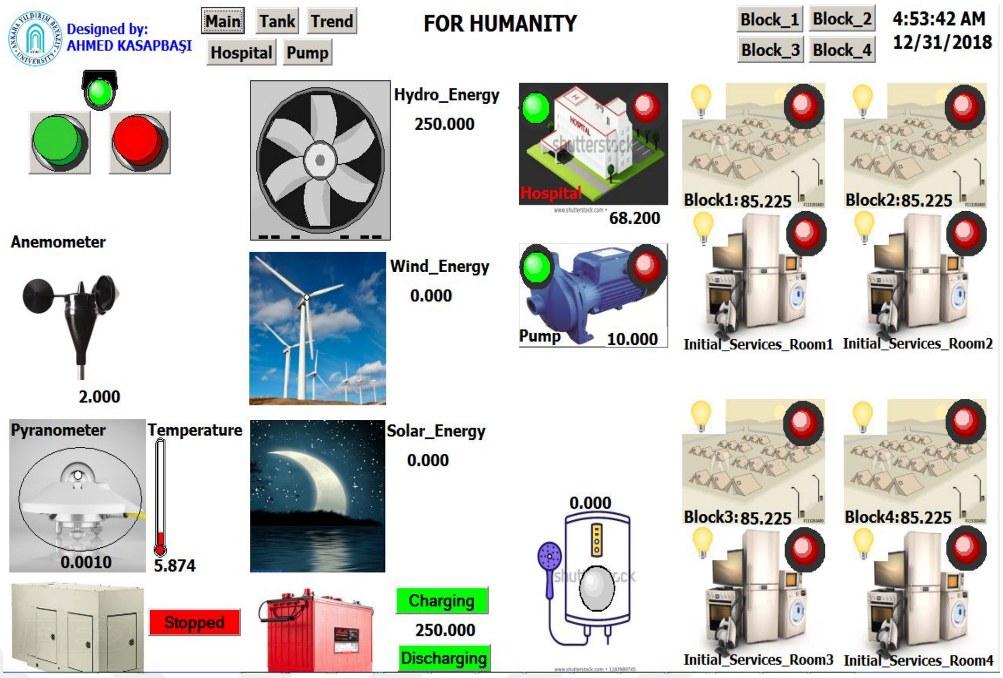


Figure 8.17 HMI-The SCADA interface when load_maximum & hydro_minimum & wind=0 & solar=0

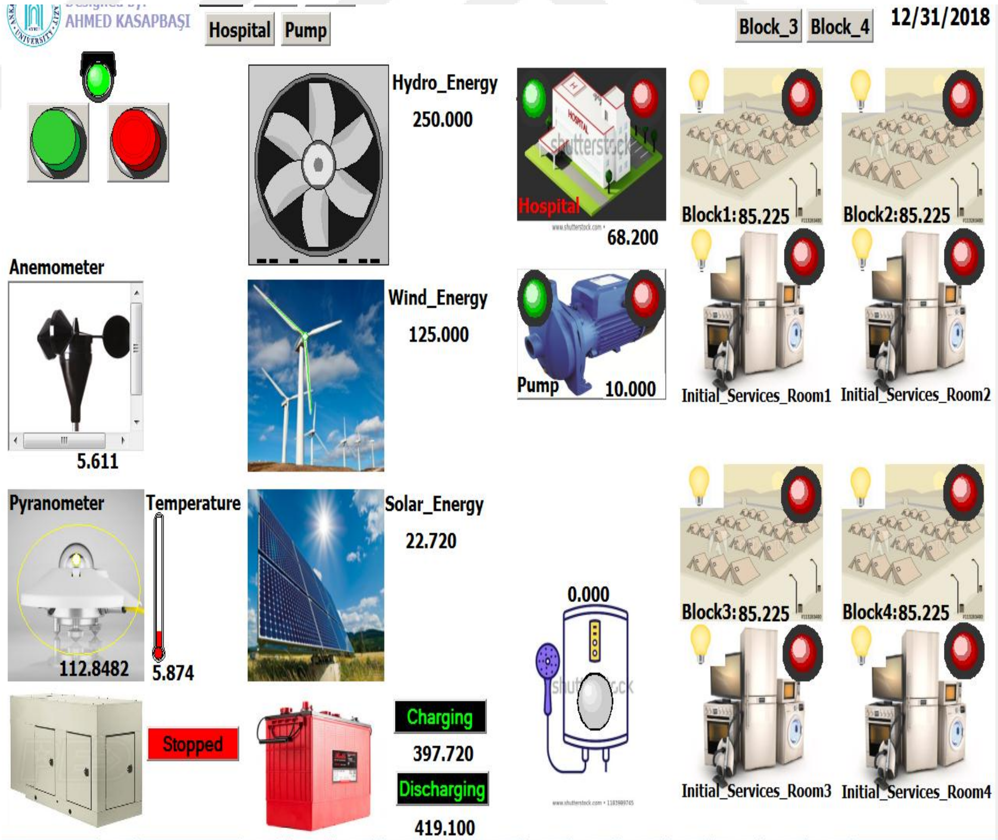


Figure 8.18 HMI-The SCADA interface when load_maximum & hydro_minimum & wind_half & solar_half

B. The load is minimum and its value is 42.8 kW, hydro power is minimum and the battery is charged: we can write the following table.

Table 8.7 The load is minimum & hydro is minimum & battery charged

Hydro	Wind	Solar	Sum	Load	Battery	Results
55 kW	0	0	55 kW	42.8 kW	Charged	State 5
55 kW	27.5 kW	5 kW	87.5 kW	42.8 kW	Charged	State 5
55 kW	55 kW	10 kW	120 kW	42.8 kW	Charged	State 5

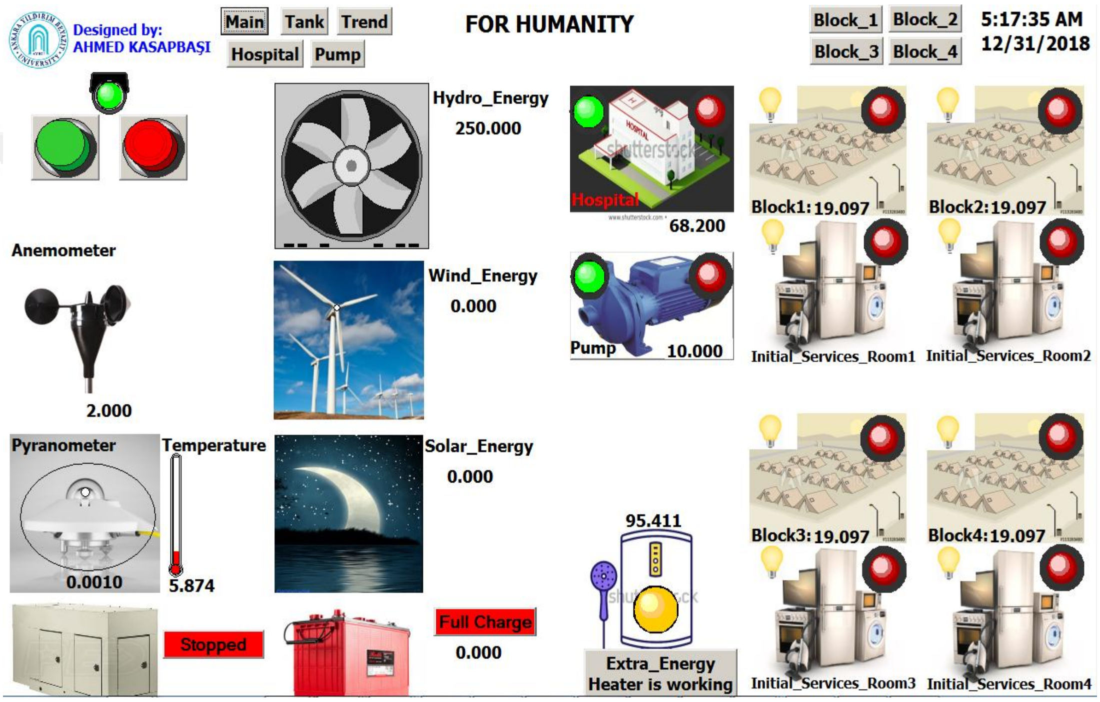


Figure 8.19 HMI-The SCADA interface when load_minimum & hydro_minimum

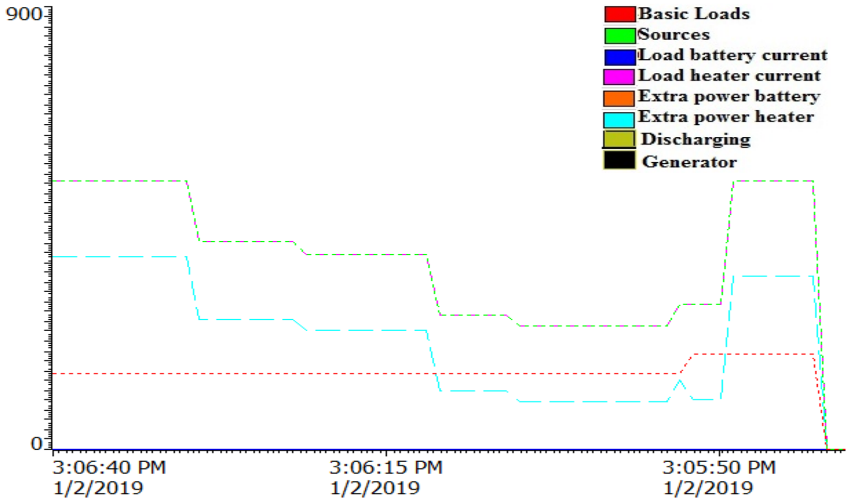


Figure 8.20 The prospected cases when the load_minimum & hydro_minimum

C. The load is minimum and its value is 42.8 kW and hydro power is minimum: we can write the Table 8.8 illustrates the suggested states.

Table 8.8 The load is minimum & hydro is minimum & battery not charged

Hydro	Wind	Solar	Sum	Load	Battery	Results
55 kW	0	0	55 kW	42.8 kW	Not Charged	State 4
55 kW	27.5 kW	5 kW	87.5 kW	42.8 kW	Not Charged	State 4
55 kW	55 kW	10 kW	120 kW	42.8 kW	Not Charged	State 4

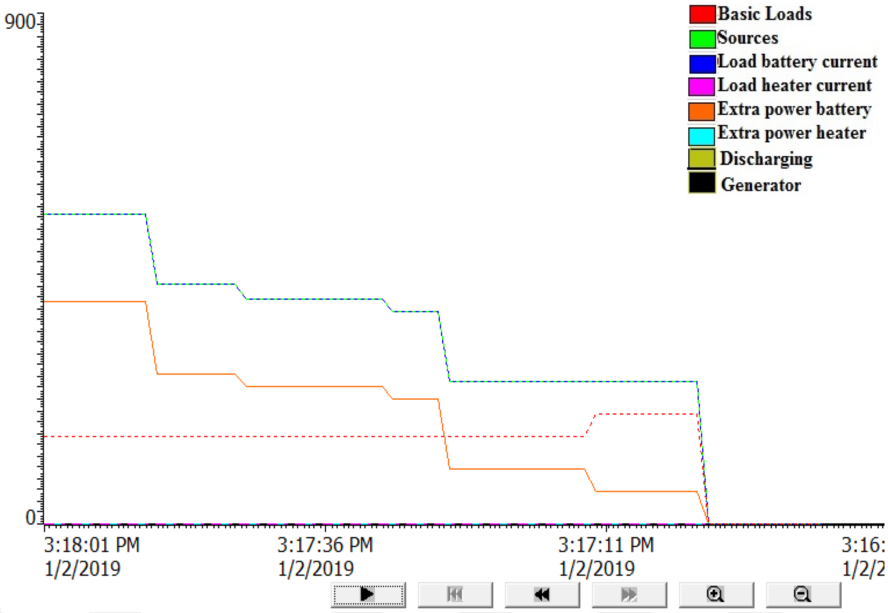


Figure 8.21 The load is minimum & hydro is minimum & battery not charged

D. The load is maximum and hydro power is maximum but battery not charged: we can write the following table.

Table 8.9 The load is maximum & hydro is maximum & batteries not charged

Hydro	Wind	Solar	Sum	Load	Battery	Results
110 kW	0	0	110 kW	100.3 kW	Not Charged	State 4
110 kW	27.5 kW	5 kW	142.5 kW	100.3 kW	Not Charged	State 4
110 kW	55 kW	10 kW	175 kW	100.3 kW	Not Charged	State 4

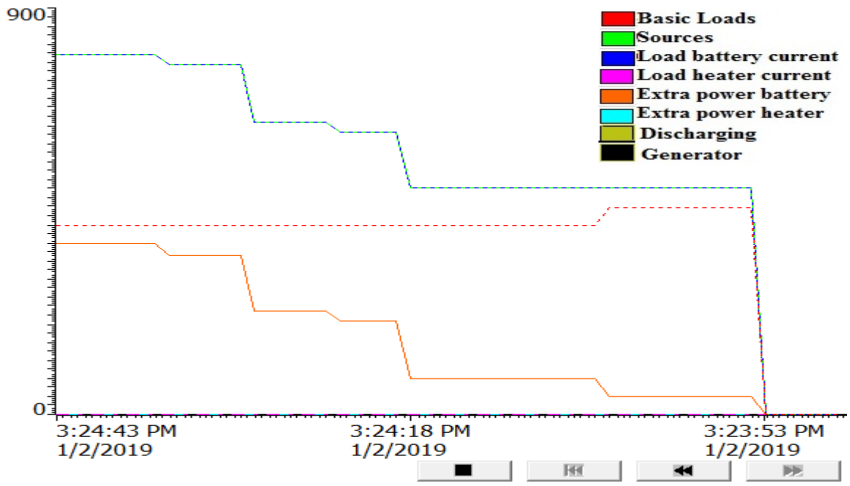


Figure 8.22 The load is maximum & hydro is maximum & batteries not charged

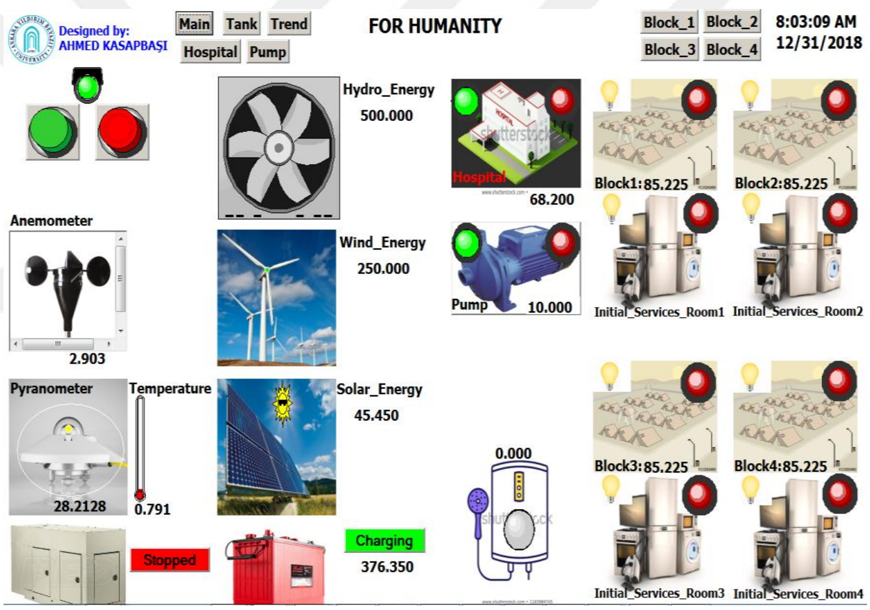


Figure 8.23 HMI-The load is maximum & hydro is maximum & batteries not charged

In addition, the system has the ability to cut off the current from the block that consumes energy more than the amount allocated to it. Where the initial services room is just fed with the necessary electricity while the supply of tents, which are inside that block, is stopped until consumed power comes back to the permitted amount for that block. We mentioned earlier that each tent can consume around 500 W as a maximum power, if every block contains 25 tents that means that the maximum power which can be consumed by tents of each block is 12500 W plus 6250 W for initial services room, that means that each block can consume 18750 W as a maximum power. If this amount rise a little, the SCADA system will cut off the current from the tents of that block until the people stop the excessive consumption and the SCADA system show that to supervisor. Figure 8.24 illustrates one of these state where the generated power is 100 kW from hydro power, for example, where the fourth block consumes more than 18750 kW (18750/220=85.227 A) which is allocated for each block. This way work to distribute the power in abalanced manner.

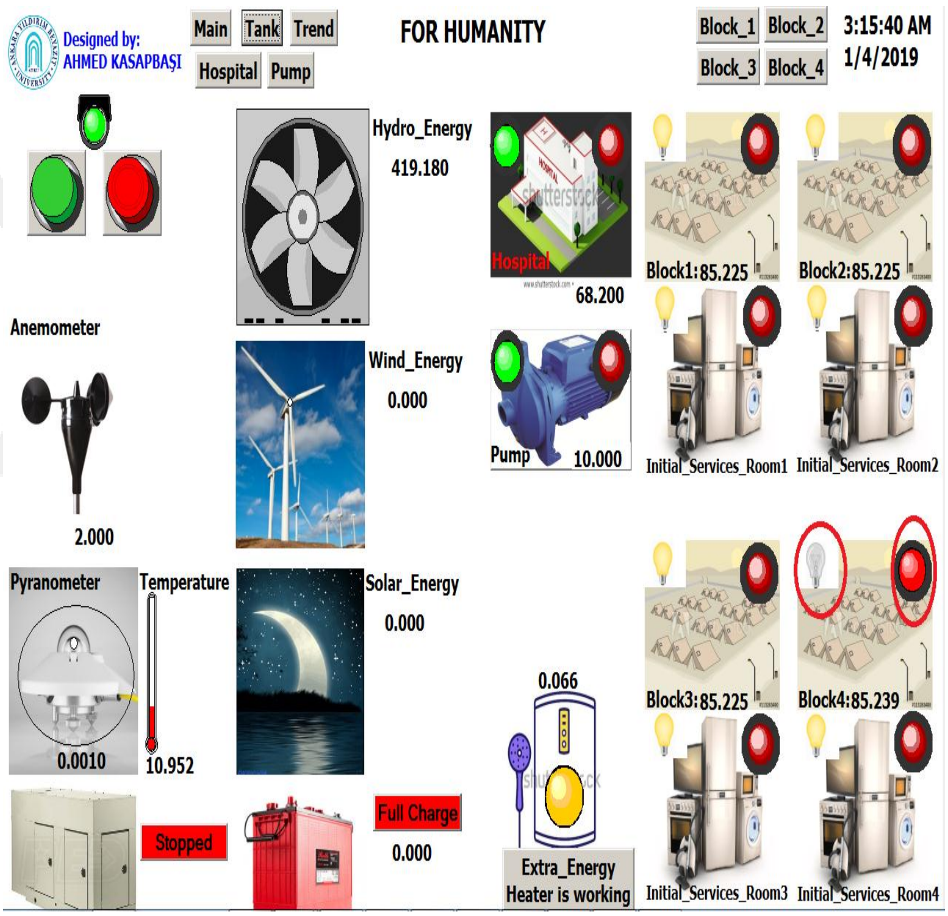


Figure 8.24 HMI-The fourth block consumes excess power

According to the diagrams and simulator, we find that the control system achieve its tasks well with ability to improve it. The system can deal with all the expected cases and emergency. It can estimate which source feed the load and which one charge the battery and how much energy there are. In addition it can know when there are extra energy and where it can be used. Compared with the search which is in the fifth reference, for example, our system is more professional,reliable and developed because it depends on three clean power sources that means increasing the reliable of the system and the fifth reference's researcher depended on designing a prototype to perform his search with sample possibilities, for example he/she used a small controller with limited possibilities that forced him/her to design out circuits for collecting data from variety sensors and his/her controller is not expandable for that it can not be used in professional work or in big tasks. On the other hand, our thesis suggested professional SCADA system with an integrated system of sensors, logic controller and other components. In addition our system is expandable. May be we could not implement our system in real time like in the fifth reference, but the suggested SCADA system introduced the possibility of test the system by integrated programs group which is suggested in our thesis for proving the effectiveness of the suggested system that introduced good and expected results.

CHAPTER 9

CONCLUSION AND FUTURE WORK

9.1 Conclusion

Many regions around the world suffer from the lack of electricity for many reasons such as the public network is far, especially in rural and remote areas, or because of wars that destroy all aspects of life. In addition to the lack of traditional energy sources such as oil and gas, which suffer from high price and its harmful effects on the environment and society. For that, a lot of communities and countries direct towards using an other power sources which are available in the environment of that community like solar and wind energies, but the main disadvantage of these sources that is not available all of time because of the weather and climate variability. For solving this problem, it is suggested combination of using the two sources together for increasing the productivity, so that they complement each other, but this system is limited possibilities and expensive. For that, it is suggested to benefit from flow of rivers water which is considered as clean and sustainable source for generating the electricity by using new technics that do not need to build the dams. Although flow of water has been changing during the year but it is available day and night albeit with more smaller rate. Where rivers water are often used by building the dams on them, but these dams are harmful to the environment and society and need a huge and institutional work.

In this thesis, the problem of supplying a refugee camp with the electricity is solved by suggesting a use damless hydro power which depends on new technics, but because of changing flow of river water, it had to be supported the hydro power via using other energy sources like a solar and wind to make the system more reliable and continuity.

The proposed sources need a control and supervision for exploiting the produced energy optimally, so that it was suggested a integrated SCADA system with sensors and transducers. This system is the focus of this thesis. the suggested system prove its ability to achieve the control operation by the best way for feeding the loads (refugee camp) with the required energy and exploiting the excess energy to avoid the waste a lot of power. That can be achieved by using an improved strategy which depends on comparing the produced and consumed energy, then it will be fed the loads with the required power and the excess energy is used in other useful works. The control system works to process most of the expected prospects.

Comparing with previous studies, most of the studied systems depend on two power sources and use inefficient control system that conduct to reduce the age of system and its other components and probably stop providing the load with power whereas the suggested SCADA system with the improved control strategy will supply the refugee camp or any suggested place which has the same conditions with the permanent and stable electricity continuously. In addition all produced power are utilized without wasting a lot of energy. Moreover, it is considered that use this control system increase the default age of the system because of using a group of the smart sensors which help the system to use the part that is generated the power inside. In addition to observation, which is introduced by this system, helps the client to find the faults, thus the maintainance is more easier. Not only that but also when there is a fault in one of unit power, the other units continue in work, that means more reliable. Consequently, the proposed system is considered more reliable, security, effective, longer life and solved a humanity problem.

9.2 Suggestion of Future Work

The future work of this work can extend to:

1- Applying this project as a hardware.
2- Controlling the energy of tents one by one to increase the reliable and effective of the system.
3- Setting up more hydro turbines to export the produced power to some near houses by SCADA system.
4- Increasing the clean power generators like solar panels, wind turbines and hydro turbines to try for cancelling the use of fuel generator and that can be achieved via SCADA system.

5- Adding a fourth clean source power to the system like biogas power and performing the control operation by SCADA system.
6- Converting the system to more smartter system by means of connecting it with internet web sites which can provide the system with the data about weather in advance.

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CURRICULUM VITAE

PERSONAL INFORMATION

Name Surname : Ahmed KASAPBAŞI

Date of Birth : 01.01.1989

Phone : 05054251506

E-mail : ahmdqassabashi@hotmail.com

EDUCATION

High School : Al-Thawra School.

Bachelor : Al-Baath University.

Master Degree : ANKARA YILDRIM BEYAZIT UNIVERSITY (AYBU).

WORK EXPERIENCE

Research Assist. : Aleppo (Halep) University (Previously)

TOPICS OF INTEREST

- Control Systems
- Microcontrollers
- SCADA Systems
- Electronics circuits