GENERATING ELECTRICITY BY USING SEWAGE WATER

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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I am dedicating this thesis to my parents. Who always pray and supported me.

ABSTRACT

Every day we produce lots of sewage water. This sewage water has some potential energy which can be used in useful way to produce electricity. Need for electricity is also increasing day by day. To fulfill these increasing needs of mankind we are focusing to build micro hydropower plants by using instead on macro power plants that need large amount of capital investment. In this thesis we are focusing to build a micro hydropower plant utilizing the sewage water in efficient way. For this purpose we will use Archimedean screw will be used. Proposed idea for this generated electricity is to illuminate the street lights at time of need and rest of the time electricity can be stored on the super capacitors. We can utilize this stored energy for other purposes or it can be transmitted to the smart grid.

Matlab simulink has been used in this thesis to design the Archimedean screw, generation system (gear box and alternator), AC to DC converter and transmission system for the smart grid.

Keywords: Sewage water, Supercapacitors, Archimedean screw, Waste water, Micro hydropower plant, Electric power, Matlab, Smart grid.

ÖZET

Günlük atık su kullanımı miktarı göz önüne alındığında kanalizasyon sistemlerinden atılan atık sular elektrik enerjisi üretimi için bir kaynak oluşturabilir. Bu tez Arşimet türbini (Vidası) kullanarak atık su yardımıyla elektrik enerjisi üretimi üzerine yapılan araştırma sonuçlarını içermektedir. Matlab simulasyonu için sistem tasarlanmış ve simulasyon sonuçları değerelendirilerek sokak aydınlatması ve/veya akıllı şebeke entegrasyonu için uygulama imkanları irdelenmiştir.
Anahtar kelimeler: Atık su, Süperkapasitör, Arşimet Vidası, Matlab, Akıllı Şebeke.

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ABBREVIATIONS

AC:	Alternating Current
AT:	Archimedes Turbine
DC:	Direct Current
EDLC:	Electrical Double Layer
EMF:	Electro Motive Force
GESW:	Generating Electricity by Using Sewage Water
GS:	Grid Station
HEP:	Hydro Electric Power
HP:	Hydro Power
KW:	Kilo Watt
Li-ion:	Lithium-ion
MHP:	Micro Hydropower Plant
NEC:	Nippon Electric Company
pf:	Pico Farad
PI:	Vacuum Pressure Impregnated
RPM:	Revolution Per Minute
WH:	Watt Hour
ηF:	Micro Farad

CHAPTER ONE
INTRODUCTION

1.1 Overview

In this chapter, first introduction is explained then arrangement of all chapters, further next complications and nature of problem, literature review, and in last block diagram of this thesis work are explained.

1.2 Introduction

Electrical energy has become essential part of life. Nowadays, progress of any country depends on its electric power generation capacity. We know that oil and gas will end in next few decades. Therefore it’s very important to find every possible way to produce electricity which may minimize oil and gas usage.

In developed countries where sewage of the city is high and it’s routed towards small canal, it can be used to produce electric energy.

This sewage has untreated raw sewage. Mainly water pollution caused by sewage, from chemically treated, raw sewage and liquid waste of industry [1].

There are number of sources to produce electricity like hydraulic power, wind, coal and nuclear.

Electricity from hydraulic is cheaper and eco friendly. A bigger dam is mandatory to generate power in megawatt (MW). To build a big dam big capital cost and hefty land reforms are required.

Therefore, there is another available option sewage water can be used to generate electricity. It can be used with some chemical treatment or without any treatment.

In this work, Archimedes screw turbine will be used to produce electrical power through waste water. It has 82% efficiency even if head is 1 meter higher.

For this purpose, in first step a micro hydropower plant (MHP) will be designed. Then produced power will be delivered to the nearby houses and additional energy will be supplied to grid station (GS) through smart grid system or it can be stored in batteries or super capacitors for local backup.

The aim of this proposed research work is electricity generation from sewage water by using MHP along with Archimedes turbine, particularly in those regions that are close to sea shore. Then, the MHP is integrated along with existing Grid Station (GS), thus that additional energy could be diverted from MHP to GS.

Broadly saying the aim of this thesis is to design such a system that can use sewage water, flowing downwards naturally, to generate electricity.

1.3 Thesis Arrangements

This thesis consists of six chapters and the summary of each chapter is described below.

Chapter 1 describes introduction, thesis arrangements, research work is divided in-to three parts complications and nature of problem, literature review, block diagram.

Chapter 2 describes waste water, rainfall, supercapacitor, smart grid, Archimedes turbine, synchronous generator, hydropower plants.

Chapter 3 summarizes calculation for micro hydropower plant (MHP).

Chapter 4 explains Archimedes turbine simulation in Matlab simulink, gear box in simulink, connection of synchronous generator with gear box, interconnection of MHP with distribution system.

Chapter 5 summarize conclusion along with future works.

1.4 Research work division

Research work is divided in three parts. The first section would be the micro hydropower generation system. It consists of two basic elements i.e. generator and turbine. The most important part in the designing of hydro power plant is to choose suitable turbine. In the scenario of low head, Archimedes turbine would be preferred.

Major parts of micro hydropower plant (MHP) are turbine, low speed rotating shaft, gears, and generator.

The most important part of a micro hydropower plant (MHP) is electrical power generator.

For small electricity generation where flow rate of water changes the entire year there resultant power will vary and the power quality may become poor. It may cause the damage of equipment. A correct control mechanism is installed to prevent the equipment, and primarily focus is retained on the voltage and on a frequency of system, and it tells us about the power quality of a system.

Synchronous electrical generators as well as 3 phase and single phase induction generators are available. However synchronous generator is generally more suitable for (MHP) [2]. In figure 1.1 research work division is shown.

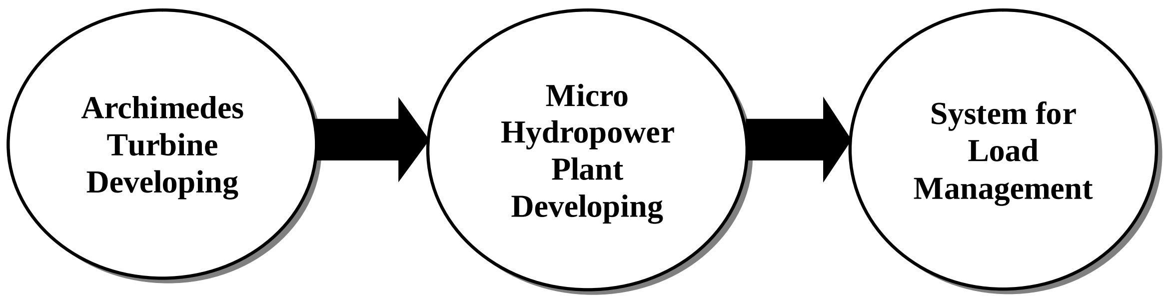

Figure 1.1: Research work division

1.5 Complications and Nature of Problem

The characteristics associated with this task are complicated. Main properties of the complications of task are described below.

- Nonlinearity geometry of the Archimedes screw design.
- Complicated designing of micro hydropower plant (MHP) and interlink with already existing system while considering a constant voltage and frequency of a distribution system.

1.6 Literature Review

Nowadays, nobody can deny that electricity is just like a breath for this modern technological era. Today's world has become a global village. Day by day we are adopting different new things in our lives. Our houses are controlled according to the weather. We have cold and hot weather according to our needs. We have new gadgets to use like smart phones, smart watches, laptops, iPods, iPads. We have electric cars, trains. Our cities are more lighten and colorful at night through different lights and digital screens. Now industries are growing by leaps and bounds on daily basis.

All these things need electricity to stay operational. As a result, we need more electric power with every passing day. There are number of ways to produce electrical energy, but renewable sources are more demanding because oil and gas will end sooner or later.

Therefore it's good idea to build micro and mini power plants. We are focusing to build small hydro power plants because the power generated by these is cheaper. Therefore it can be wise option to use sewage water as a hydraulic power source.

There is another way to use sewage water as a biomass purposed in [3], and then use this biomass gas to burn in a boiler as a fuel. Then through this biomass electricity is produced. Because this biomass produces methane gas [3].

Road side water canal can be used to produce electricity presented in [6]. It has small head and can produce power at a small scale.

There are already some researches done on Archimedean screw. Earlier this device was used to pump the water upward from downward for irrigation [4]. However in recent researches on this area it is found that Archimedean screw has a new application working inversely as a power converter with regard to low head differences [5]. Archimedean screw as a power converter gives efficiency between 78% and 84%, which makes it a fascinating option for turbines in low head hydro power plants [7].

1.7 Block Diagram

Figure 1.2 shows all steps that will be performed to design GESW. Here water source is waste water. Then, in next step there is water tank which produces water force that produces mechanical power in screw. In next step gear module is interconnected with screw and Alternator, and this gear module transfer mechanical power from screw to alternator. Then alternator gives electrical power at output which can be supplied to smart grid or DC convertor. DC converter converts AC power into DC power and here this power can be stored in batteries or super capacitors for local purposes.

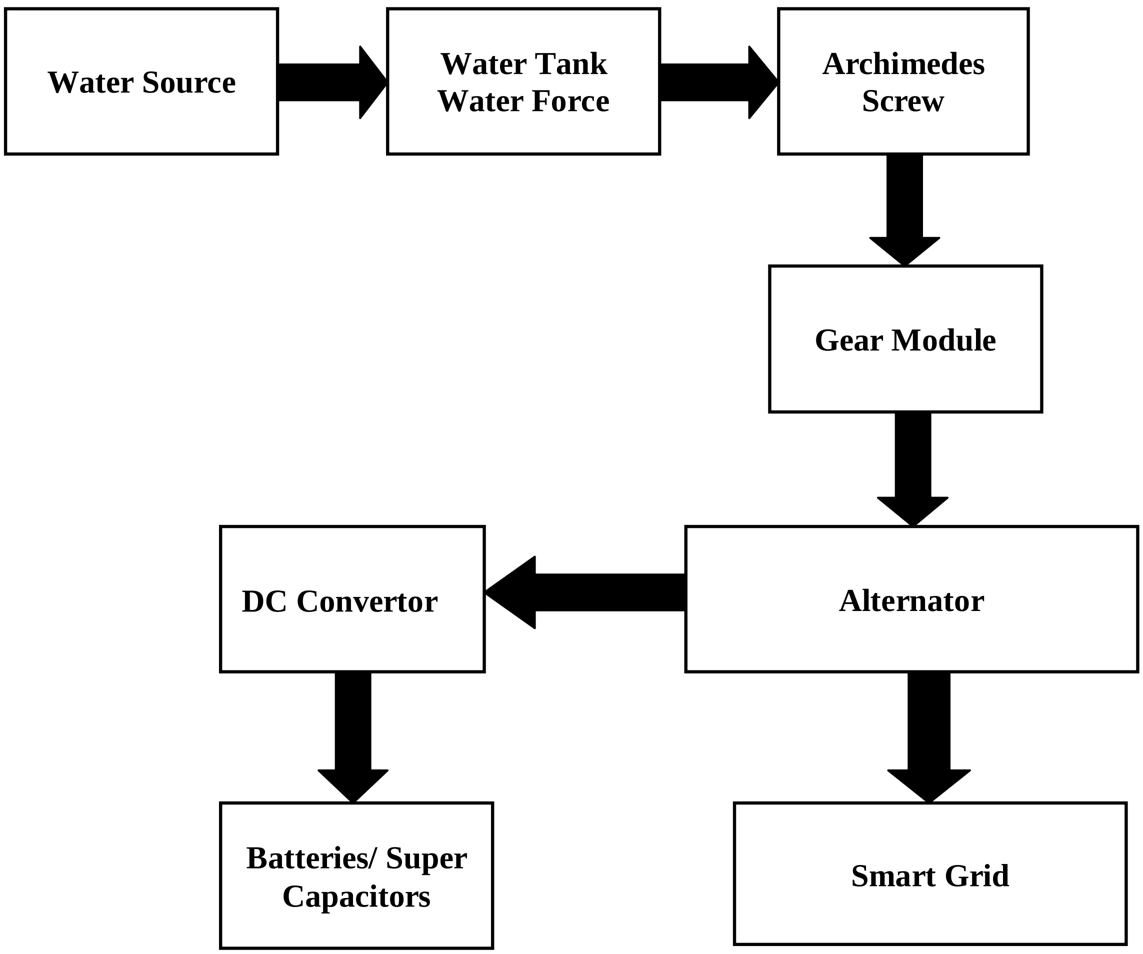

Figure 1.2: Block diagram GESW

1.8 Summary

In this chapter, introduction was discussed. Then arrangement of all chapters, complications nature of problem, literature review, and block diagram of this thesis work were explained.

CHAPTER TWO
ELEMENTS OF PURPOSED SYSTEM

2.1 Overview

In this chapter sewage water, alternator, synchronous generator, smart grid, supercapacitors, Archimedes turbine are discussed. Furthermore, micro hydropower plant will be discussed and problems associated with it will be discussed.

2.2 Sewage

Sewage is actually that water which contained waste materials, in solvent form that's supposed to be eliminated from a housing area. It’s also called waste water and it has around 99% of water. Sewage is characterized by the physical condition, volume or flow rate as well as toxic ingredients, and also the bacteriological microorganisms that it consists of.

Sewerage water made up mostly associated with grey water (through kitchen sinks, bathtubs, showers, meal as well as clothes washers, and lavatories) and also the human waste materials that the toilets flush away, soaps as well as detergents and toilet paper [1].

Figure 2.1 shows sewage water. Sewage eventually ends up in the environment, by some of several routes. Sewage generally moves from a building's plumbing system in a sewer, which will take it somewhere else, or in to on-site sewage facility.

Figure 2.1: Sewage water [8]

A basic distinction in the route is whether or not it is handled by any means in order to reduce its impact on the environment before arriving there. Many counties put there sewage into sea. Some countries put sewage in rivers.

This sewage has untreated raw sewage. Mainly water pollution comes from by chemically treated and raw sewage and liquid waste of industry [1].

This polluted sewage causes turbidity and deoxygenation. It's also cause problems for eco system. Because of sewage in many countries sea water is not safe for swimming and bathing. Sewage causes degradation of environment, destroys fisheries [9].

Before in the last century, sewers generally dropped into a river, lake, bay, or sea. There was no cleaning treatment method before dropping into lake, bay or sea, therefore all the human waste was left to the environment. However these days, sewers route their contents to a body of water through wastewater treatment plant rather than directly. In several countries, it has become norm, however in some countries, it's not like this.

Average daily water use by a person

According some surveys in United States, this estimated vary, each person uses (70 to 95 gallons) 130 to 160 liters of water in his daily life. Maybe it's little surprise but it's fact that we use most of water to flush the toilet, bathing and showers [10]. Table 2.1 shows a daily usage of water by a person in a day.

Table 2.1: Daily water usage at home

Bath	36 gallons	137 l
Shower	2.5 g/ m. Older shower heads 4 g/ m	10 l/ m
Toilet flush	2 gallons / flush	8 l / flush
Teeth brushing	1 g/ m	4 l/ m
Hands/face washing	1 gallon	4 l
Face/leg shaving	1 gallon	4l
Dishwasher	20 gallons/ load	75 l/ load
Dishwashing by hand	3 g/ m	11 l/ m
Clothes washer	Uses about 40 gallons per load	151 l/ load

2.3 Rain

Everybody knows rain is droplets water from a sky. This water comes from evaporation of atmospheric water and it becomes heavier in form of clouds and then due to gravity it comes down in the form of rain [11].

Rainfall is an important element of the water cycle. Rain is one of the biggest sources of fresh water on the Earth. It is also important part of ecosystems, and it is used for crop irrigation as well as for hydroelectric power plants [11].

In mountainous areas, we have heavy rain falls. In many areas of the world there is heavy rainfall during winter and monsoon season also brings heavy rains in many parts of the world like south asia.

However in big cities in populated areas and main roads this rain water flows towards sewage pipes and produces big sewage water. This water can be used to produce electric power through Archimedes screw.

2.3.1 How Many Baths Are Possible From A Rain Storm?

When we have a big rain over a house, just simply how much water are we getting?

Suppose house area is around 2023 m^2 (.5 acre) and we are getting that rain which drops 2.5 cm (1 inch) of rain. Then, we have got 51395 liters (13,577 gallons) of water on our yard. A big bath takes 150 liters (40 gallons). Hence, if we could preserve that water it's enough for 339 baths. Figure 2.2 shows rainfall.

Figure 2.2: Rainfall [12]

2.4 Alternator

An electric machine that changes mechanical power into Alternating Current electrical power is known as alternator. Most of alternators have stationary armature and rotating magnetic field due to the simplicity and cost factor. Only some time rotating armature and stationary magnetic field is used.

Its field or armature rotated by any other mean, in our thesis it will rotated by a turbine throw gears. Output frequency depends on which generator is driven. It is also known as synchronous generator [13].

2.4.1 Use of alternator

Before, DC generators were use to produce electric power but when alternators came into picture, the DC dynamos were replaced by alternator. Alternators are used in electric locomotives. These are driven though diesel engine and then this AC electric power is used in the form of DC by converting through rectifiers. It's also use marine. Marine has 12 to 24 output voltage level. For large power more than one, units are used.

2.5 Synchronous Generator

A synchronous machine is that operate as a generator. These machines have constant frequency. These machines are used in power house, transportation systems. Synchronous Generator first time was used in 1870's by a P. N. Jablochkov. He invented the arc lamps known as Jablochkov candle.

In synchronous generator, rotor winding is connected with a DC current source to produce a magnetic flux in rotor. Then this rotor is moved through an external source which produces a revolving magnetic flux. This revolving magnetic flux induces electro motive force (EMF) in three phase stator windings.

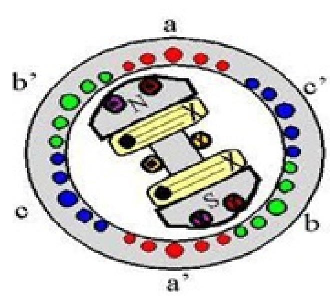

Figure 2.3: Synchronous generator

Synchronous generator is shown in figure 2.3. It consist of rotor which positioned on revolving fixture of the machine i.e. in above figure a rotor is shown. In Figure 3.3 induced three phase voltages in armature conductors are shown by ‘aa” ‘bb” ‘cc”. Rotors of these machines are driven by a water turbines or steam. Rotor windings are excited by a DC current and it can be done through a separate generator or rectifying current. When rotor moves its magnetic field induces a three phase voltage in stator windings. Nowadays this three phase electric power generation technology is used in generation stations.

2.5.1 Rotational speed

As from definition, we know that synchronous generators are those machines whose generated electric frequency is synchronized with the mechanical rotational speed.

This EMF frequency is

$$f = \frac{P}{120}(N) \tag{3.1}$$

Where

f = Electrical frequency in Hz

P= Number of poles pairs

N= Rotational speed of rotor it’s rpm.

Synchronous generator has fixed armature winding and rotating field winding unlike the DC generator where the arrangements are exactly opposite.

2.5.2 Stator

In synchronous generator where the voltages are induced it’s called stator. This is the static part of machine and it’s coupled with rotor through mutual induction. The frame is made to tolerate the challenges exerted by mechanical forces and electrical forces in core and supply low vibration amounts. Stator structure is composed of insulate windings and a core. The core of electric lamination is made from high grade silicon steel. Laminations have space for ventilation to ensure the cooling in whole core and stacked properly to support all structure. The windings are vacuum pressure impregnated (VPI) with a global process using a two part epoxy resin. VPI system gives good dielectric strength, high resistance against moisture, for long life of generator.

2.5.3 Rotor

The moving part of synchronous machine is called rotor. There is a winding on rotor to produce magnetic flux. Synchronous generator rotor is a large electro magnet. Rotor has a spider on which the field poles, damper, windings and exciter armature are mounted. The rotor spider designing depend the runaway speed requirement. The rotor spider can be made of steel with field pole, by using higher strength bolts, or forged with dovetail as per requirement or laminated dovetail sheets. The magnetic poles are constructed in two ways, they can be salient or nonsalient [14].

Rotor has a laminated construction to reduce eddy current losses.

There are two types of rotor used

- Salient pole rotor
- Cylindrical rotor

2.5.3.1 Salient pole type

Salient pole (Figure 2.4) type rotors have small axial length and large diameters. Such types of alternators are bigger in size and looks like a wheel. These types of rotors are used for low and medium speed machines. These are made of thick laminated steel sections riveted together. These are attached with rotor through joint.

Figure 2.4: Salient rotor with large number of poles [14]

2.5.3.2 Cylindrical rotor type

Cylindrical rotor (figure 2.5) type machine looks like a cylindrical because it has a uniform length in all directions. This cylindrical shape gives a uniform flux cutting in all directions. In this case rotor consists of a smooth solid steel cylinder. It has a number of slots along its outer periphery for hosing the field coils. These types of rotors are utilized for high speed operations. These types of machine give less windage losses.

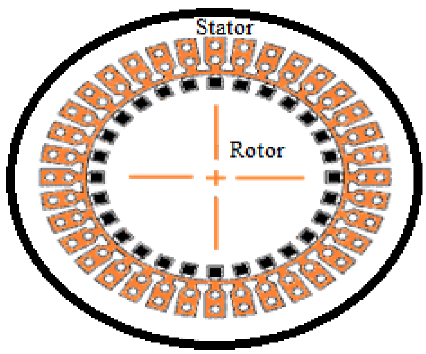

Figure 2.5: Cylindrical rotor [14]

High speed generators have 1 or 2 numbers of poles and they are use with steam and gas turbines. Steam turbines have more efficiency when rotated at high speed. Usually these kinds of machines have 3000 (rpm) to generate 50 Hz with 2-poles. These are used for steam turbines.

$$N = \left(\frac{120.f}{P}\right) = 3000 \text{ rpm} \qquad (3.2)$$

Four pole type running at a speed of

$$N = \left(\frac{120.f}{P}\right) = 1500 \text{ rpm} \qquad (3.3)$$

f =50 Hz.

Synchronous generators which are used with water turbines has high number of poles. Water turbines have good efficiency when rotated at low speeds (200-300) rpm.

2.5.4 Magnetizing dc current

There are two typical methods to magnetize the rotating rotor windings through a DC current.

- External DC source
- Exciter Generator

2.5.4.1 External dc source

In this method, DC power is provided to rotor winding from external source by using slip rings and brushes. Slip rings are insulated with shaft but they are encircled the shaft.

2.5.4.2 Brushless exciters

In this method, DC power is provided through a source which is mounted directly on the shaft of machine. Brushless exciter is a small alternator. Its armature winding circuit is mounted on the rotor shaft of synchronous generator and field winding circuit is mounted on stator of synchronous generator.

Brushless exciter is a small alternator which produces three phase AC but here for magnetization we need DC. Therefore for this purpose three phase rectifier is used that is also mounted on the shaft. Field current of synchronous generator can be controlled by controlling DC field current.

2.6 Smart Grid

2.6.1 Conventional electric grid

In figure 2.6 conventional electric grid is shown. In all countries, electric grid consists of many power plants in different parts of countries. It has thousands of km long transmission and distribution lines. However, this system is running successfully from many decades, but population is also increased and the equipment using electricity at the user end of the lines has become increasingly sophisticated [15].

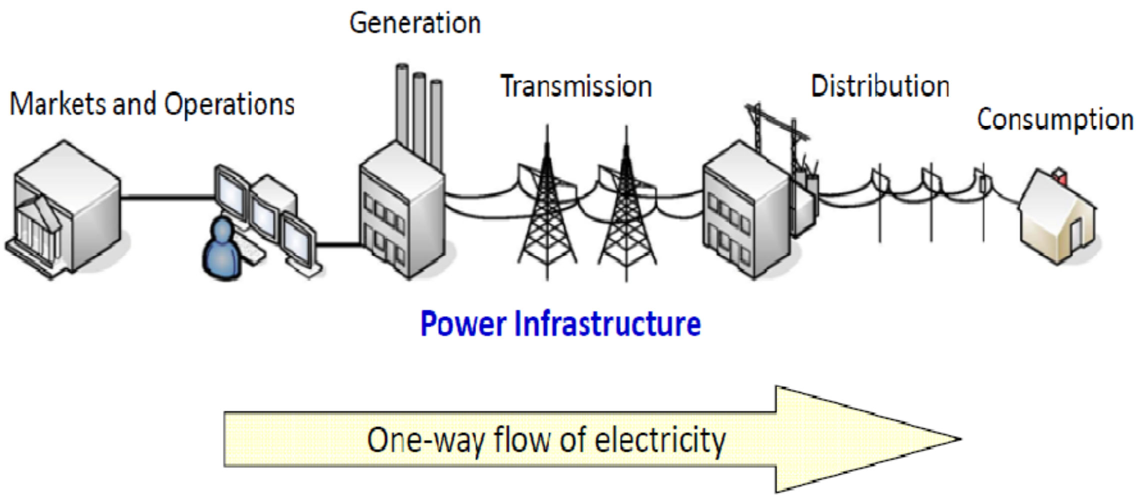

Figure 2.6: Conventional electric grid [16]

Nowadays electric grid system is facing many challenges

- It is older
- Inefficient (the delivered efficiency of electricity is only 35%)
- Vulnerable (black outs)
- Centralized generation
- Heavily depend on fossil fuel
- Nominal automation
- Nominal situational understanding

The old grid system has old equipment which can't handle both renewable energy sources, because these energy sources are less predictable than fossil fuel generators. In addition, the electrical grid is not set up to handle the demands that are being placed on it by end-users.

To solve above described issues smart grid gained lots of importance. A smart grid can be defined as a modern electricity network system which could protect, monitor, and automatically optimizes the operation of its interconnected elements [16].

2.6.2 What are smart grids?

In smart grid systems information technology and other advanced technologies are used to monitor and manage the transmission of electric power from generating station to users.

Smart grids communicate between generators, grid operators and users, because it understands the needs and capabilities of all generating stations [16].

As shown in figure 2.7 it can be seen it is a two way power system architecture that allows dual way communication between the grid and other devices which are connected to it, all the way.

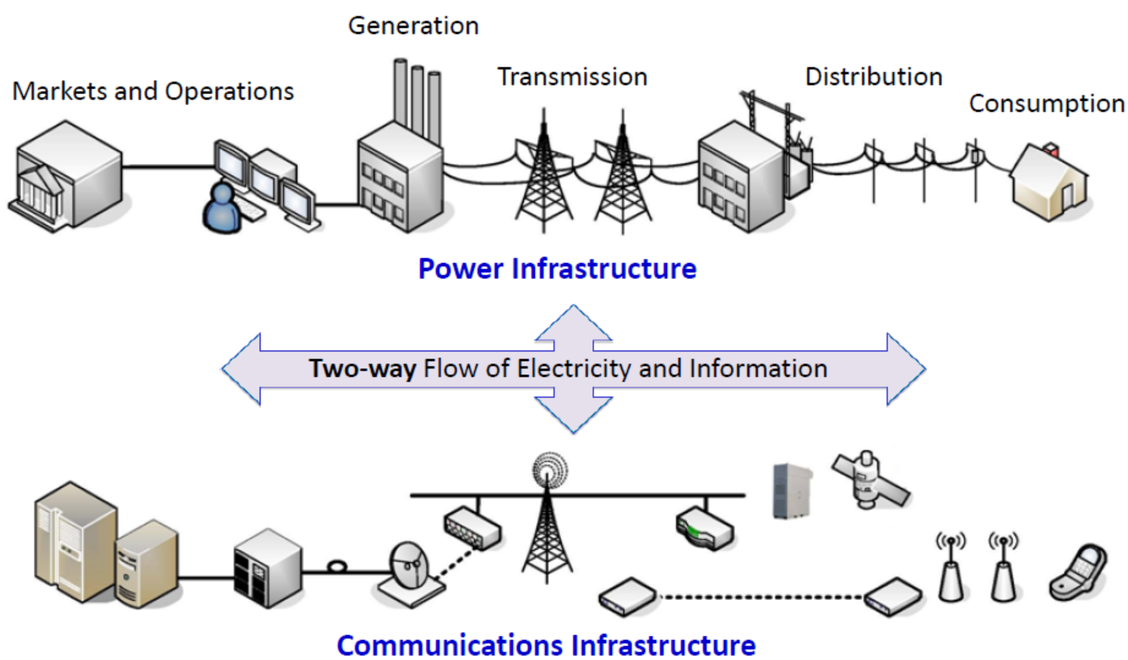

Figure 2.7: Smart grids infrastructure [16]

2.7 Capacitor

Leiden jar invented capacitor in 1745, since that time a tremendous progress started in capacitor technology. In starting capacitors were used in electric and electronics products, but nowadays they are use many fields like space and aircrafts, games, medicine, automobiles, computers and power supply circuits.

A capacitor stores energy in the form of static charge as opposed to an electrochemical reaction [17].

Capacitor has typical specifications around 20 µF to 2 Farads and 5.5 to 6.3 Volts [18].

Capacitors can be grouped into three generations

2.7.1 First generation

In figure 2.8 electrostatic capacitor is the most basic capacitor. It has dry separator and very low capacitance. It's used to tune radio frequencies and filter signals. It's rated from a picofarad (pf) to low micro farad (µF).

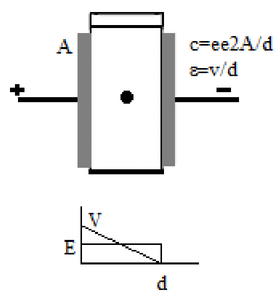

Figure 2.8: Electrostatic capacitor [19]

2.7.2 Second generation

The second generation capacitors are electrolytic capacitors with moist separator, which are used for coupling, and power filtering. These capacitors have ratings in microfarads (µF). These types of capacitors have thousands times greater storage capacity than the electrostatic capacitors. Electrolytic capacitors electrode are made from tantalum, ceramic, and aluminum where solid or liquid electrolytes are used as a separator in between two electrodes [17]. Electrolytic capacitor shown in figure 2.9.

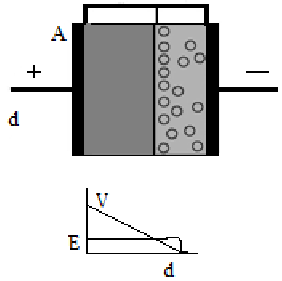

Figure 2.9: Electrolytic capacitors [19]

2.7.3 Third generation

The supercapacitors shown in figure 2.10 are also known as double layer capacitors. The super capacitors are third generation capacitors and rated in farads. Super capacitors have thousands times greater rating compared to electrolytic capacitors. These are suitable choice as energy storage device. Supercapacitors have rapid charging and discharging time, and higher life cycles at high current. Supercapacitors have high capacitance value [20].

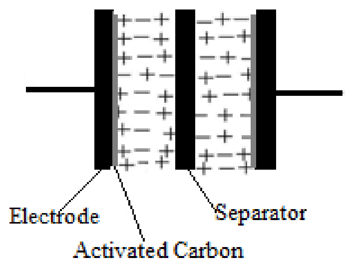

Figure 2.10: Supercapacitor [19]

2.7.4 History

In 1957 general electric engineers developed supercapacitors while they were experimenting on double layer capacitors. But after that there was no known usage of this till 1966. Then in 1966, company name standard oil discovered it again during experiments on fuel cells design. Then they licensed this to NEC, and NEC started commercialization of this in 1978. They launched this in market for computer memory backup, with the name of supercapacitors. These carbon electrodes based capacitors were used in many electrical devices like camera, VCR, etc since 1978. Later on in 1980 they were used in used wrist watches with solar cells and 10 year after engineers started using in another use of these were started in toys, home equipment.

Although this concept had been initialized and developed some forty years ago, but there was a limited progress on this topic till recent times. In recent times increased demand of energy storage devices raised interest for its revival.

2.7.5 Supercapacitors

Supercapacitors some time called electric double layer capacitors (EDLC), or ultracapacitors. They work like batteries [18]. Supercapacitors are such wonderful energy storage devices, which fill the gap between capacitors and batteries. Because supercapacitor stores more energy compared to typical capacitors and it have high power density than batteries. So this feature make it good choice for various power needs like electronic power devices, for storage solar energy, wind energy and hybrid vehicles.

Although supercapacitors are not batteries, but they enter in battery technologies boundary by employing particular electrodes and electrolyte.

Supercapacitor works on double layer capacitor principal, where electric field is produced between electrodes due to applied voltages and it causes the migration of electrically charged ions towards the opposite polarity. Therefore, double separate charged layers are produced. It has long cycle life because there is no chemical action involved in this process. Activated carbon is the main component of electrode construction. It can store charge around 106 Farad [18].

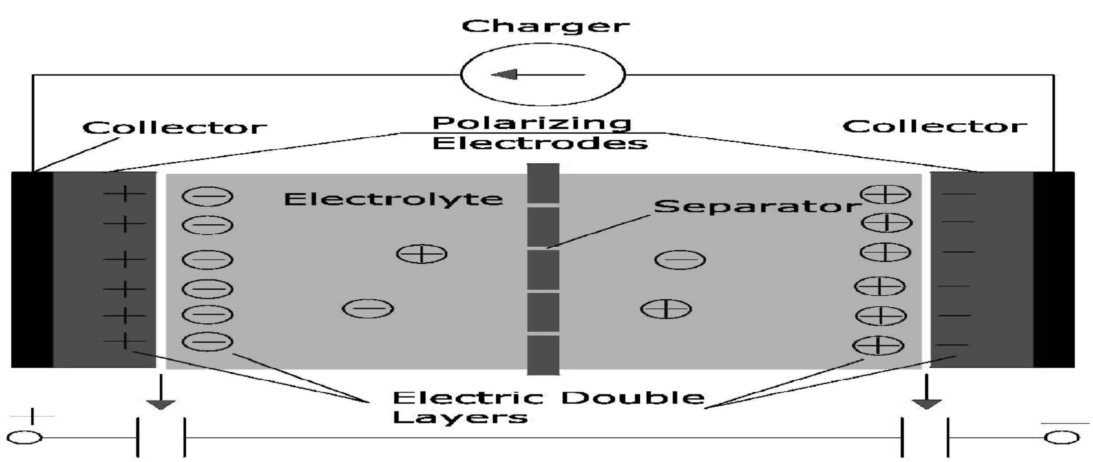

Figure 2.11: EDLC configuration [20]

In Figure 2.11 an electrical double layer capacitor configuration is shown. Where electric charge stores between electrode and electrolyte interface [20].

There are two main types of supercapacitors

- Electrical double layer capacitor
- Super or pseudo capacitor

2.7.6 Comparison of supercapacitor and typical lithium-ion battery

In table 2.2 a comparison between supercapacitors and Li-on batteries is shown.

Table 2.2: Supercapacitor and typical Li-ion battery comparison [20]

Feature	Li-ion	Supercapacitor
Charging time	10 to 60 min	1to10 sec
Life Cycle	500 h and high	1 million to 30,000 h
Cell volts	3.6 V	2.3 to 2.75Volts
Specific energy	100–200 (Wh/kg)	5 (Wh/kg)
Specific power	1,000 to 3,000 (W/kg)	Up to 10,000 (W/kg)
Working life	5 to 10 years	10 to 15 years
Charging temperature	0 to 45°C	–40 to 65°C
Discharging temperature	–20 to 60°C	–40 to 65°C

2.7.7 Advantages and constraints of the supercapacitor

Table 2.3 below shows Advantages and constraints of the supercapacitor

Table 2.3: Advantages and constraints of the supercapacitor

Advantages	Higher cell voltages possible Higher power available Higher power density Charging methods are simple Fast charging and discharging No chemical actions No overcharging Unlimited cycle life more than 500,000 cycles Longer life around 20 years Lower impedance
Constraints	High cost per watt Linear discharge voltage characteristic prevents use of all the Lower capacity Cell balancing required for high cell voltages Higher self discharging rate

2.8 Archimedes Screw

2.8.1 Archimedes Screw history

According to the historic records, the Syracuse King wants to assemble a luxurious and huge ship to show his hometown supremacy and dignity. Archimedes was best in geometrical designs, mathematical understandings and sophisticated understanding of the concepts related to buoyancy. Therefore, his design had a problem. The ship take huge amount of water because ship was leaky and threatening the seaworthiness of the vessel.

Therefore Archimedes came to a problem with a solution. He designed a screw by applying his knowledge and creativity. Archimedes device was elegant in its simplicity. A single person was able to operate this device and it was the best way to pump the water from a bilge. Later on, this device became very popular in agriculture irrigation. Since that, with the passage of time, this device design was utilized for many other applications, many historians write that this device led.

2.8.2 Archimedes Screw Pump

Archimedes screw is the earliest type hydraulic machine and still is utilized. Before, it was used to carry the water upward from lower level to upper level. In figure 2.12 Archimedes screw pump is shown.

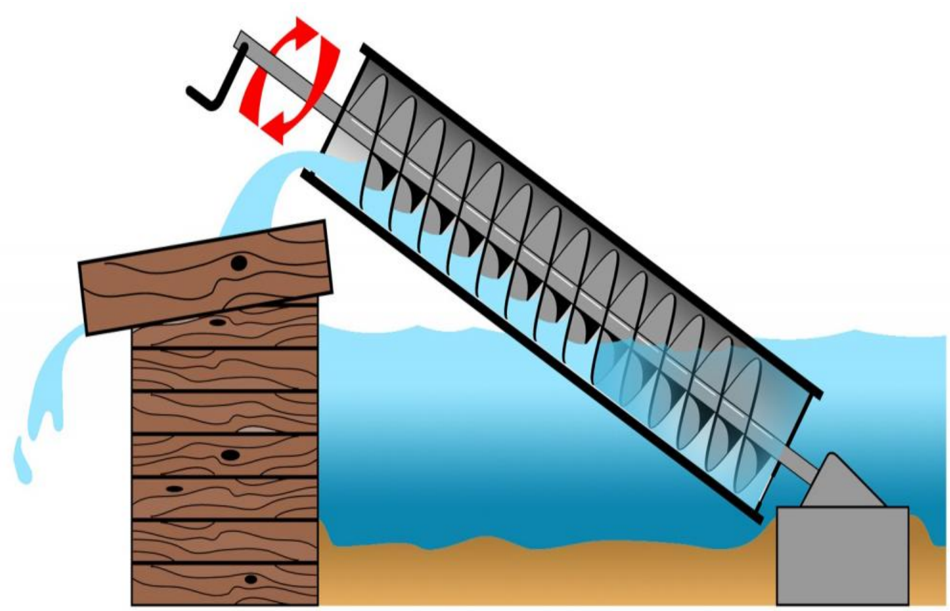

Figure 2.12: Archimedes screw pump [21]

Historically Archimedes screw was used to transfer water for irrigation lands and ditches from low level water bodies. Acutely this device was used by Archimedes to get rid of from leaked water into ship. This method is still in use in many modern applications as well due to its effectiveness. In simplest form a screw pump consists of a screw in a hollow tube with the help of a shaft [22].

An Archimedes screw pump figure 2.12 is a simple machine, which lifts water upward when it's rotated. It's utilized since ancient times. It was used primarily for transfer of water from a lower level to upper level, such as ponds or rivers, in order to irrigate land fields, and also for draining water from mines.

The lower section of the screw dips in the water, and water travels along the tube in spiral form with its rotation. In the meantime more water is scooped up at the end of the tube and it moves along, and so on until the water arrives out the top of the tube.

This machine was developed by a Greek scientist Archimedes (250 B.C). He was not only a scientist at the same time he was also an engineer and mathematician. He belongs to Sicily, and studied in Alexandria, Egypt.

Even though, the Archimedes screw was invented in ancient times, it has been adapted throughout time. Because of the simplicity of how it works, the Archimedes screw can be eco friendly.

2.8.3 Archimedes Screw Turbine

Archimedes screw also can be use as turbine, only if we change its working mechanism. If water flow downward from upper level. This water will produce hydraulic power which will produce force on blades and screw will start moving. If we connect gearbox at the top and further this gear box is connected with generator, then we can get electric power at output.

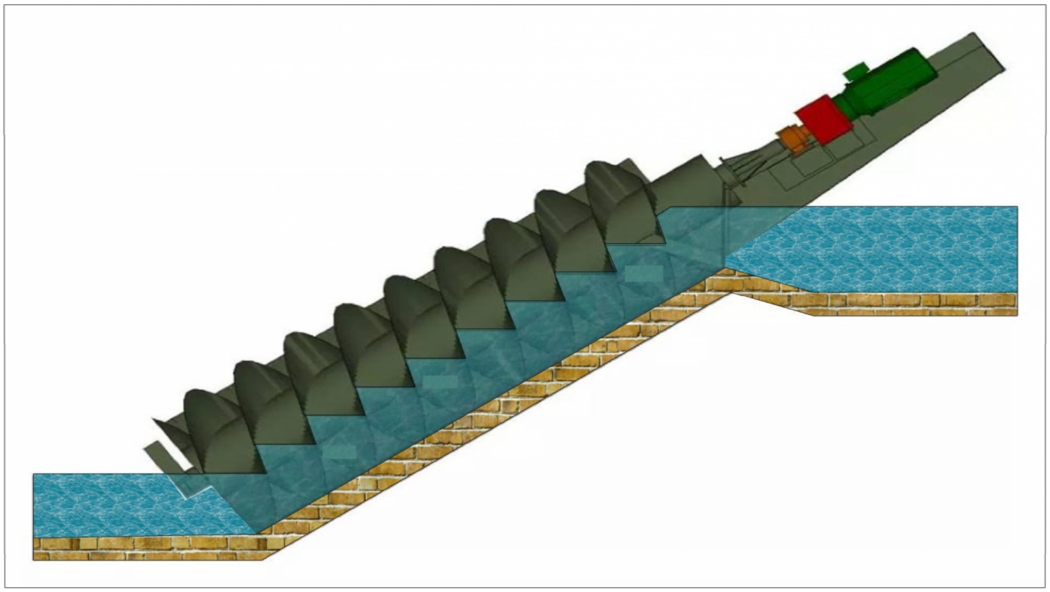

Figure 2.13: Archimedes turbine

In figure 2.13 Archimedes turbine is shown. Sewage flow rotates this screw and then it is connected with a generator which produces electric power.

2.8.4 Advantages

The Archimedean hydropower screw has following advantages compared to classic turbines

- It has high efficiency under any condition
- It has self regulation with water flow change
- Installation is small and simple
- It has easy implementation in existing situations
- Long life time
- Operates completely without fine screen
- Less running costs
- Quick return on Investment

2.9 Hydro Electric Plants

Falling and flowing water have some potential energy. Hydro power comes from converting power in flowing water by means of water using a turbine into useful mechanical energy. By using electrical generator this energy is converted into electric power. For hydro power plants big dams are required to build [23].

Mostly hydropower plants are built by a government and these are multi purposes projects. Dams provide flood control, irrigation, water supply, fisheries. Hydro power has many benefits, its clean and renewable source. No pollution like fossil fuels. They are eco friendly. Water is still reusable after it. Figure 2.14 shows a hydropower dam.

Figure 2.14: Hydropower dam [24]

Although there are also some obstacles as it can affect the surroundings significantly. Big reservoirs may cover towns, scenic locations and farmlands, as well as wildlife habitat.

2.10 Classification of Electric Plants

- **Large hydro Plant**: Above 100 MW usually feeding to grid
- **Medium hydro Plant**: 15 - 100 MW usually connected with a grid
- **Small hydro Plant**: 1 - 15 MW usually connected with a grid
- **Mini hydro Plant**: From 100 kW, up to 1 MW
- **Micro hydro Plant**: Above 1kW below 100 kW
- **Pico hydro Plant**: From 300W, up to 1kW usually stand alone

2.11 Micro Hydropower Plant

A Hydro electric power plant which produces between 100KW to 1000KW is known as mini electric power plant and the one which produces between 1KW to 100KW is categorized as micro electric power plant [2, 25].

In big hydro electric power plants water is stored in a big dam and then transported to turbine through penstock, and it induces torque in turbine as well as eventually rotates the coupled shaft which is attached to gearbox, and then to generator, which produces electricity.

However in the case of micro hydro electric power station it's not compulsory to build a bigger dam or water stocking channel. Therefore with the use of low head water resources along with high flow, hydro work will be less complicated and civil work will be reduced.

2.11.1 Background of micro hydropower plant

All over the world, the large part of electrical energy originated from hydraulic Energy [26]. Modern electric power plants consist of large number of thermal power plants and hydropower plants in combination with various other electric power sources to meet with varying consumer demands.

Thermal energy or other energy productions are expensive and power generation through water is cheaper. It has less functional and maintenance cost. Other than that getting power from water is actually environmentally friendly. Therefore in this context of micro hydro electric power plant it is a good option to use sewage water in order to produce electricity. Capital expense as well as operational and maintenance cost can be minimized by collecting waste water at one place. Therefore a system can be designed that is beneficial enough to meet the needs of consumer. It can provide extra electric energy to GS incase, if consumer demands are less.

MHP is more essential alternative energy source and possesses a high significance in developed countries where government cannot keep the costs associated with the electric grid station, transmission lines and distribution lines. Though MHP is not an innovative idea but it's extremely important in the monetary terms as well.

MHP primarily has smaller rating which is one of the main reasons, to use it for a single user or small number of users. The types of small systems get importance where we have small head and quick flow rate. The turbine used in this thesis work is known as Archimedes which was developed by Greek scientist named Archimedes.

A Greek history writer Diodorus Siculus (circa first century B.C.) wrote, in an island which was in the delta of the Nile men irrigate the whole island by the means of a certain instrument conceived by Archimedes of Syracuse, and it was called (Cochlias) simply because it was like spiral or screw [27]. Figure 2.15 shows am old Archimedes screw pump working, two men are rotating screw to lift up the water.

Figure 2.15: Old Archimedes pump [23]

2.11.2 Abilities of MHP

- A modern MHP should be able to
- Fulfill the consumer load demands
- Establish a virtually excellent generating station
- Efficient coordination scheme between load shifting from local power station to electric grid station.
- Satisfy system parameters.

No doubt MHP has many benefits but the dynamic nature behavior, make it complex.

2.11.3 MHP complexities

- Some MHP complexities are following
- Civil work elements
- Electric power house elements
- Drive system
- Connection and load management with current grid system [26]

Civil work elements make complex, location selection and designing and raise the price of system.

Electric power house has a turbine, and it is the important part of it, and the nonlinear designing of turbine make it more complex to build MHP.

Drivelines connect the output of turbine and generator to convert mechanical energy into electrical energy. Resultant output electric power is supplied to consumer [26, 28].

In this thesis work main focus is kept on power house and reliable transfer of generated power to grid station.

2.12 Categorization of MHP Problems

We can split MHP complexity in two parts, first one related to electric power house, transmission to load and load management.

2.12.1 Electric Power House Issue

Electric power house contains turbine, alternator and control unit. It has simple structure however it should have concrete floor [29].

In power house the choice as well as style of turbine is the most complex issue compared to other problem. In this work emphasis has made on Archimedes screw turbine especially for sewage.

2.12.2 Equipment Problem

Hydropower plant (HP) which has capability to generate 100KW is called micro hydropower plant (MHP). In this plant hydraulic energy which is produced by water is used to rotate turbine and its produces torque in turbine. Further it’s connected to Generator through gear box, which produces electricity [25]. Generator is the most important part of power house design. There are lots of choices available in Generators for use like induction, synchronous and axial flux (AC & DC) generators [30].

2.13 Optimization of MHP Problems

In this thesis optimized design of Archimedes screw is used to design Archimedes screw in Matlab simulink. As mentioned earlier that before Archimedes screw was used as a pump to pull up the water from below surface. But from few years it is used as a turbine in many countries. The only difference between generator and pump is water flow direction. In a generator water flows downward and in a pump water flow upward [31].

A precise note about this machine was written by a roman engineer Vitruvius's in a book named De architecture. Vitruvius's screw is shown in figure 2.16 which was made of wood. It had 16 time shorter diameter then its length and it had eight blades on it.

Archimedes screw is installed in such a way that it could move about its length. In a triangle of 3-4-5, it's tilted in front of hypotenuse. However this design is no more effective. For good results of a screw a technique will be developed.

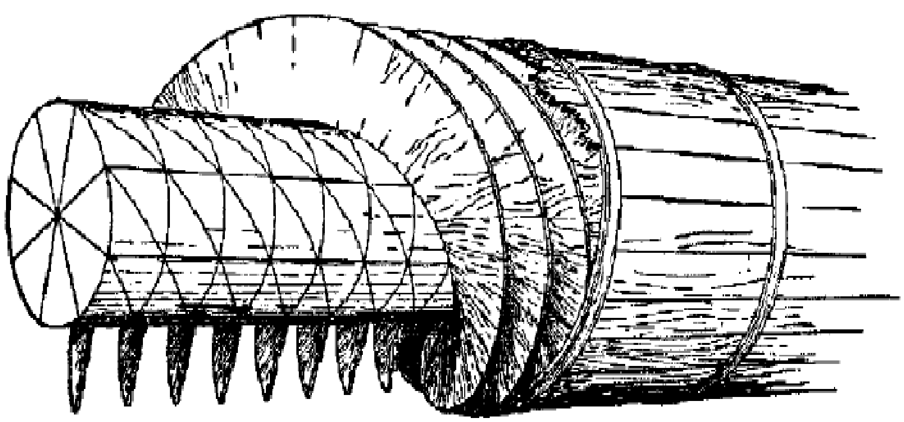

Figure 2.16: Vitruvius screw which was made from tree and have eight blades [32]

Although Archimedes screw is very old machine but there is not sufficient published data on it which could explain its comprehensive theory. Due to this reason, a site which has to be developed with Archimedes turbine is totally associated with the skills of engineer.

Available information regarding to this old device deals just with its empirical designing and optimization associated with geometry regarding to volume, height, and its water inflow speed. It’s noted that screw efficiency is associated with mechanical leakage losses as per Negal-1968 a handbook on Archimedean screw pump [25] and it’s in between 79% to 84%. [33,34,35]. Maximum diameter of screw can be 4 meter, due to exhaustion of weld, assembly and maintenance operation problems, during performance at site [36].

Assume that water has some weight at inlet, and Archimedes screw blades will hold this water, and weight of water will drive the screw. If we neglect the all losses, then all potential power (PP) will converted into mechanical power and efficiency would be 100%. As we know, the power depends on velocity and force. Power is equal to the product of force and velocity. Velocity acts on the surface of screw tangentially. Only a small amount of water will contribute in energy conservation which will rest on outer blades. It’s noticed that a huge amount of water rest on a trough of screw, which doesn't rotate [36].

When we use screw in hydraulic atmosphere, we need to make a theoretical model from geometry information of Archimedes screw. This geometric information can be collected through site assessment.

But some parameters can be predefined to have the idea of Geometry.

- Screw has N blades in inclined plane.
- Angle θ. Higher θ less efficiency and vice versa.
- Outer radius R_{out} of screw should be significantly larger than inlet water flow h_1.
- Inner radius R_{in} should be small.
- Pitch P
- Water will be trap between buckets, which will be formed through blades of screw. These buckets rotate downward while carrying water within it and because of it screw rotates. V_b is the volume of each bucket, and total N buckets volume will be $NV_b = V_u$, here V_u is that volume of water which screw will take out in one round.
- Adjacent region between two blades outer and inner radius of screw is called chute.
- If no blades is N then no of chutes of screw will be N.

One pitch length Volume is given by eq. 2.1

$$\pi\left(R_{out}^2 - R_{in}^2\right)\frac{P}{N} \qquad (2.1)$$

2.14 Summary

In this chapter, those aspects were discussed which are associated with this thesis, like sewage water, alternator, synchronous generator, smart grid, supercapacitors, Archimedes turbine. In last part, hydro electric plants and its types were described. Then micro hydropower plant was discussed and problems associated with it were discussed.

CHAPTER THREE
GEOMETRICAL DESIGN FOR ARCHIMEDES TURBINE

3.1 Overview

In this chapter geometrical parameters of Archimedes screw are discussed which are used to design this screw in Matlab simulink.

3.2 Design of Water Power Screw

Screw pumps are used from long time. First time the idea to use Archimedes screw like a hydraulic screw to produce electric energy was just presented in 90s of previous century [37]. First step of design flow begins with site assessment. In next step we find water flow and then control to determine and calculate screw dimensions. We can measure power output with screw dimensions also effective torque can be measured [38].

In figure 3.1 provided dimensions are flow rate is Q, H is drop height (Head) and the geodetic altitude the upper water level UWL, and LWL is lower water level, these parameters should be defined before. θ is the angle of screw appointing, the outer radius R_{out}, the gap width between trough and screw is S_{sp} so the trough dimensions will be R_{out}+ S_{sp}.

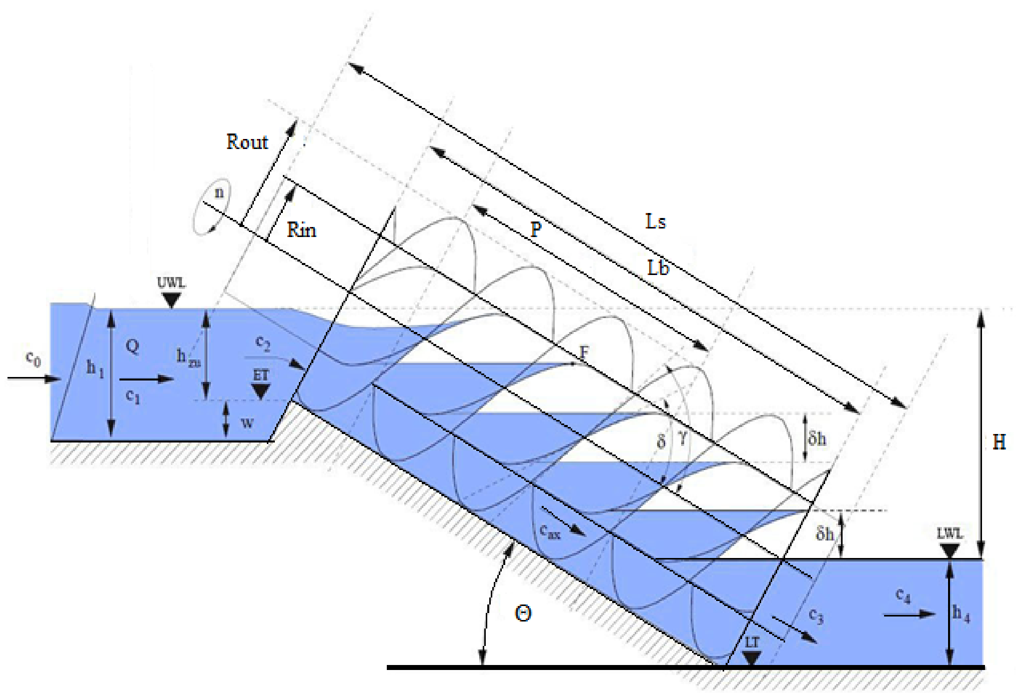

Figure 3.1: Geometrical design of screw [38]

R_{in} is the radius of central tube, and L_s is the length of Central tube. N is the number of blades and pitch is P. The blades length L_b is given as the length of screw, the angle of the blade on the outer radius is γ and inner radius is δ, the optimum water depth in the inlet channel height is h_1 and threshold height is w. optimum below water height is h_4. F is the optimum filling point.

The speed and the M is the output torque (stem, bearing design, transmission). η is denoted as screw efficiency. P_e is denoted as the nominal electrical capacity at the generator terminals.

3.3 Drive System Dimensions

The computation procedure can be executed in the subsequent way

3.3.1 Flow head and drop head

Usually it's appropriate to assume only H rather gross head H_b. Therefore only H will be used. C_1 is a water flow at upper level and C_2 is a water flow at lower level.

Gross head is

$$H_b = \frac{{C_1}^2 - {C_4}^2}{2.g} \quad (4.1)$$

3.3.2 The Inclination θ angle and the blade numbers N

The inclination to the horizontal Screw and the number of blades is the ability to swallow. For Areas having a low head and high flow θ value should be small. On the other hand θ should be high where we have high head and low flow rate.

A greater inclination increases the efficiency. One of favorable conditions for the number of blades N=3 and inclination $\theta = 25^o$ to obtain (high efficiency and high flow rate).

Inner Radius R_{in} and Outer Radius Determination, R_{out}. Maybe manufacturer gives a hydro dynamic screw and all the measurements are fixed. Or either we have to design a worm ourselves so first approximation will be outer radius.

$$R_{out} = \left(\frac{Q\,.\ \tan\theta}{K.(\lambda.v)}\right)^2 \quad (4.2)$$

Where $K = \frac{(10).\pi^2}{6.\left(\sqrt[3]{4}\right)} = 10.362$

We attain the value of ρ from table 4.1.

Inner radius will be this

$$R_{in} = \rho.\ R_{out} \tag{4.3}$$

3.3.3 Pitch

P pitch can be found through pitch ratio λ from table 4.1.

$$P = \frac{2.\pi.(R_{out}).\lambda}{\tan\theta}. \tag{4.4}$$

The value of λ can be find from table 4.1.

3.3.4 Trough and screw distance

Trough and screw distance can be measured with this equation.

$$S_{s.p} = 0.0045\sqrt{2R_{out}} \tag{4.5}$$

If a steel trough is used, then this particular measure is provided as a spacer.

3.3.5 Volume

Volume moved per revolution

$$V_u = \frac{2.\pi^2.R_{out}{}^2}{\tan\theta}.(\lambda.\nu) \tag{4.6}$$

By using the value of (λ · ν) from table 4.1.

3.3.6 Speed

Therefore speed will be

$$n = 60.\frac{Q}{V_u} \tag{4.7}$$

Speed should following this equation

$$n \leq \frac{50}{(2.R_{out})^{2/3}} \tag{4.8}$$

3.3.7 Transport velocity of axial

It is

$$C_{ax} = P.\frac{n}{60} \tag{4.9}$$

3.3.8 Volume in a cell between two adjacent sheets

Volume in a cell between two adjacent sheets is

$$V_s = \frac{V_u}{N} \tag{4.10}$$

3.3.9 Mass

$$m_s = \rho . V_s \tag{4.11}$$

3.3.10 Upstream optimum depth

Upstream optimum depth of water is from the optimum filling point F, the normalized volume ratio can be determined

$$\nu_{T.F} = \frac{Q}{\mu_R . \pi . C_{ax} . R_{out}^{\;2}} \tag{4.12}$$

μ_R is a constant.

3.3.11 The full tube partially filled

It gives this equation

$$\nu_T = \frac{\alpha_8}{2\pi} - \frac{(1-z)}{\pi}\sqrt{1-(1-z)^2} \tag{4.13}$$

In which

$0 \leq z \leq (1-\rho)$

3.3.12 The partially filled full pipe with inside the central tube

It fallow this equation

$$\nu_t = \frac{\alpha_8 - \alpha_9 . \rho^2}{2\pi} - \frac{(1-z)}{\pi}\left[\sqrt{1-(1-k)^2} - \sqrt{\rho^2-(1-z)^2}\right] \tag{4.14}$$

In which

$(1-\rho) \leq z \leq (1+\rho)$

From below equations the related angle can determined:

$$\alpha_8 = 2arc\cos(1-z) \tag{4.15}$$

$$\alpha_9 = 2arc\cos\left(\frac{1-z}{\rho}\right) \tag{4.16}$$

To determine z, we can use graphic method. Graphical method has advantage, because after that it gives an idea of exactly how upstream water level imbalances effects. One surrenders values of z = 0. . . 1, 2 before and computes various V_t values.

$$h_2 = R_{out}.z.\cos\Theta \qquad (4.17)$$

3.3.13 Hydraulic loss coefficient

$$\varsigma = \left(\frac{\pi.\nu_t}{z.2.\cos\theta} - 1\right)^2 \qquad (4.18)$$

3.3.14 The amount of the threshold w and the water depth and h_1 inlet height

For a large outflow for a given surface and low friction, favorable channel can be chose.

$h_1 = R_{out}$

The channel width at upper water level is: $b_1 = 2 * R_{out}$.

3.3.15 The height of the threshold

$$w = R_{out} - h_2 - \frac{1}{2.g}\left(\frac{Q}{h_2.b_1}\right)^2\left[1 + \varsigma - \left(\frac{h_2}{R_{out}}\right)^2\right] \qquad (4.19)$$

When $h_1 = R_{out}$, The inlet height is then given by

$$h_2 = R_{out} - w \qquad (4.20)$$

It must be noted that w is not less than 0. In any other case we need to change the parameters of Screw.

3.3.16 The optimal water depth h_4

The normalized value of lower water level

$$\tau = (1 + \rho).\sqrt{1 - \left(\frac{\lambda}{\rho}\right)^2} - \frac{2\pi.\lambda}{N} \qquad (4.21)$$

3.3.17 Under water level depth

$$h_4 = R_{out}.\cos\theta\,.\,\tau \qquad (4.22)$$

Underwater channel width is $b_4 = 2 * R_{out}$.

3.3.18 The bladed worm length calculation

Bladed screw length is given by

$$L_b = \frac{H+R_{out}(\tau.\cos\theta-1)+w}{\sin\theta} \qquad (4.23)$$

Now the water level (UWL, LWL) and the fillings of the cells are determined. So the, first part of the calculations has been completed. The following section contains the efficiency calculation the worm.

3.4 Calculations for Efficiencies

3.4.1 Screw efficiency

Archimedes Turbine efficiency is given by

$$\eta = \frac{2a+1}{2a+2} \qquad (4.24)$$

Where $a = \frac{h_1}{\delta h}$ and $\delta h = \frac{H}{N}$

3.4.2 The hydraulic power p_h

We know hydraulic power equation is

$$P_h = \rho.Q.g.H \qquad (4.25)$$

3.4.3 The mechanical shaft power P_m

Mechanical shaft power of the screw P_m

$$P_m = \eta.P_h \qquad (4.26)$$

3.4.4 The torque of the screw M

The torque will be

$$M = \frac{P_m.60}{2.\pi.n} \qquad (4.27)$$

Comparatively Torque stays constant for different flow rates, when the filling of the buckets between blades of screw kept constant. A clutch also can be use to tolerate vibrations.

3.4.5 The electric power

If the transmission efficiency for the known operating speeds, use:

$$P_e = \eta_{GB}.\eta_g P_m \qquad (4.28)$$

3.5 Ratio parameters of Archimedes screw for various numbers of blades

Table 3.1 is used to calculate different values related to the design of Archimedes screw [17].

Table 3.1: Ratio parameters of Archimedes screw for various numbers of blades

Number of blades (N)	**Radius ratio (ρ)**	**Pitch ratio (λ)**	**Volume per turn ratio ($\lambda.\nu$)**	**Volume ratio (ν)**
2	0.5369	0.1863	0.0512	0.2747
3	0.5357	0.2217	0.0588	0.2697
4	0.5353	0.2456	0.0655	0.2667
5	0.5352	0.2630	0.0696	0.2647

3.6 Summary

In this chapter geometrical design of Archimedes turbine was explained and those calculations were shown which were used to design this turbine in Matlab simulink.

CHAPTER FOUR
DESIGN, SIMULATION AND RESULTS

4.1 Overview

In this chapter, all simulink designs, results and graphs are explained. For demonstration of the idea purposed in this thesis Matlab simulink is used.

4.2 Simulation Software

In this thesis, Matlab simulink software is used for simulation. Matlab is very useful in engineering academia. There are many different options in the form of blocks to represent the different devices. But there was not Archimedes turbine in its library. So in this work a mathematical Archimedes screw is designed in simulink. For this purpose some programming has been done in Matlab and blocks are used to call the code in simulink. Next, these blocks are connected with gear box and electric generator. Further in electrical part AC to DC converter is designed which gives DC power to supercapacitors. In last stage, smart grid is designed in simulink.

4.3 Design of Screw

In figure 4.1 below an Archimedes screw design is shown

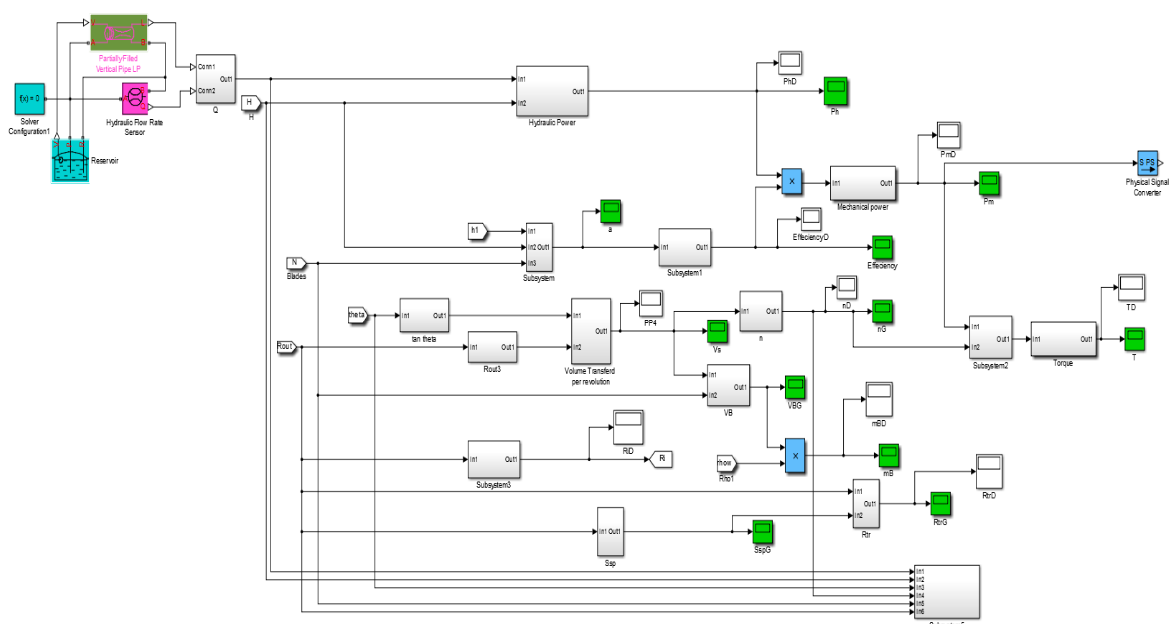

Figure 4.1: Simulink design of screw

4.4 Gear Box

In figure 4.2 below a gear box design of simulink is shown that illustrate the interconnecttion of screw output and generator input. For this purpose simple gear box is used.

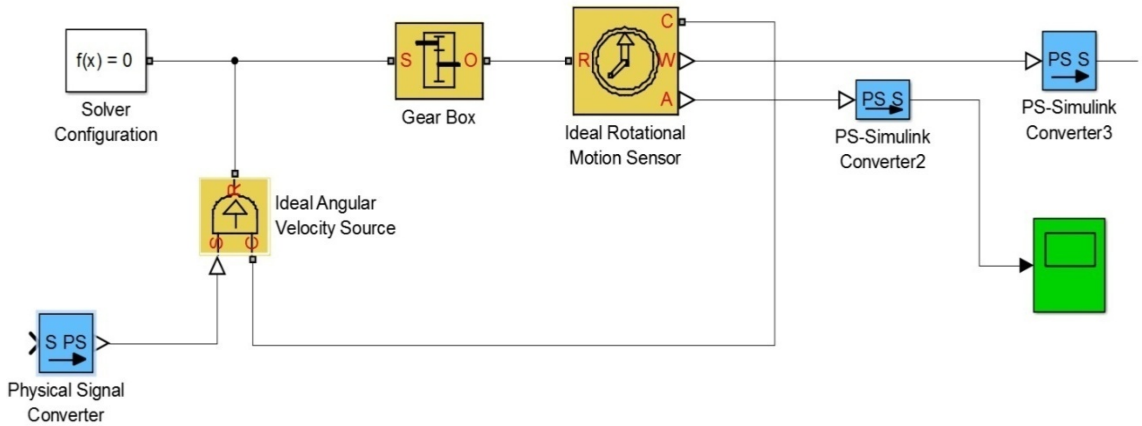

Figure 4.2: Gear box design

4.5 Electrical Design

These all electrical designing was done in Matlab simulink.

4.5.1 AC Generator

In figure 4.3 electric generation part is shown it's input is coupled with gear box which take input from screw. It gives three phase AC electric power at output this three phase electric power can given directly to grid station or can be stored in batteries or supercapacitors. Here in this work it's purposed that generated power is stored in supercapacitors for local use and further it's given to national grid system through smart grid system. Generated voltages for each phase are measured and given in figure 4.11. Therefore, this three phase output power is connected with AC to DC convertor for DC.

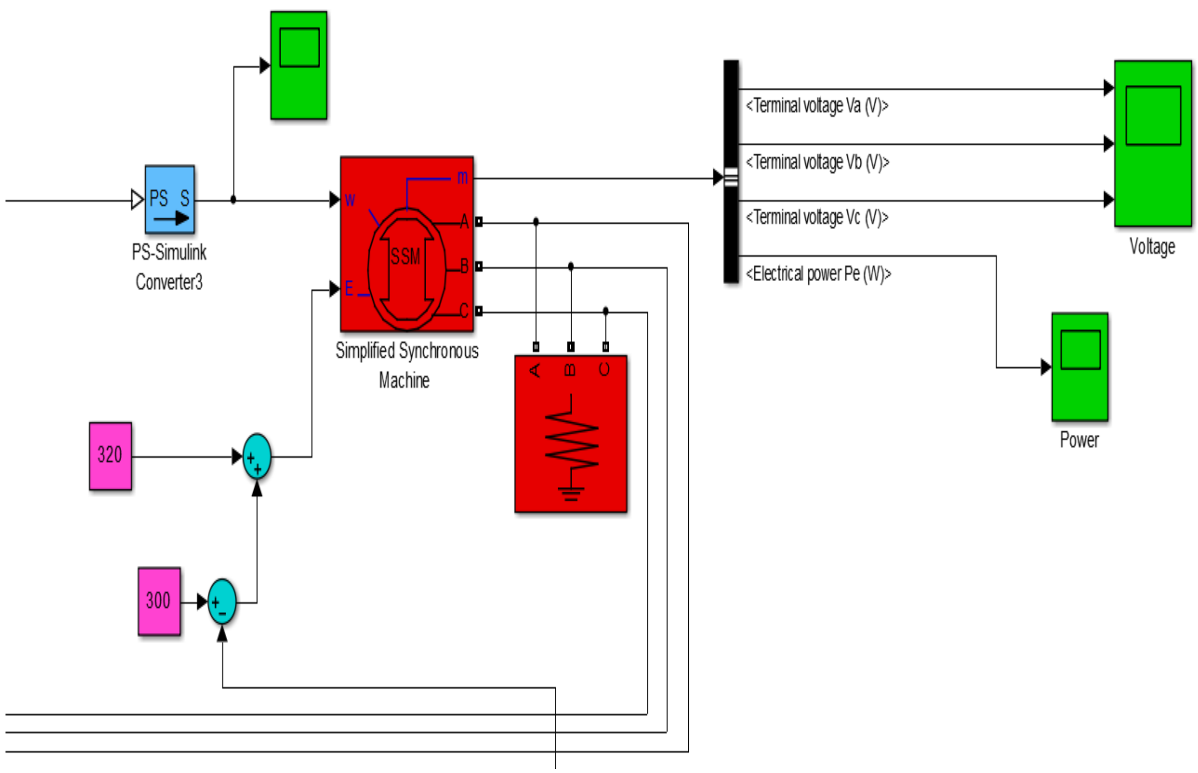

Figure 4.3: AC generator in simulink

4.5.2 DC convertor

Figure 4.4 shows the simulink design of DC convertor. It takes input from three phase synchronus generator. Here universal bridge rectifier is used. Bridge rectifier uses diodes to rectify the AC power into DC. Furthermore, filter circuit is used to eliminate the ripples and variable resistor is used. This DC power is used to charge the supercapacitors.

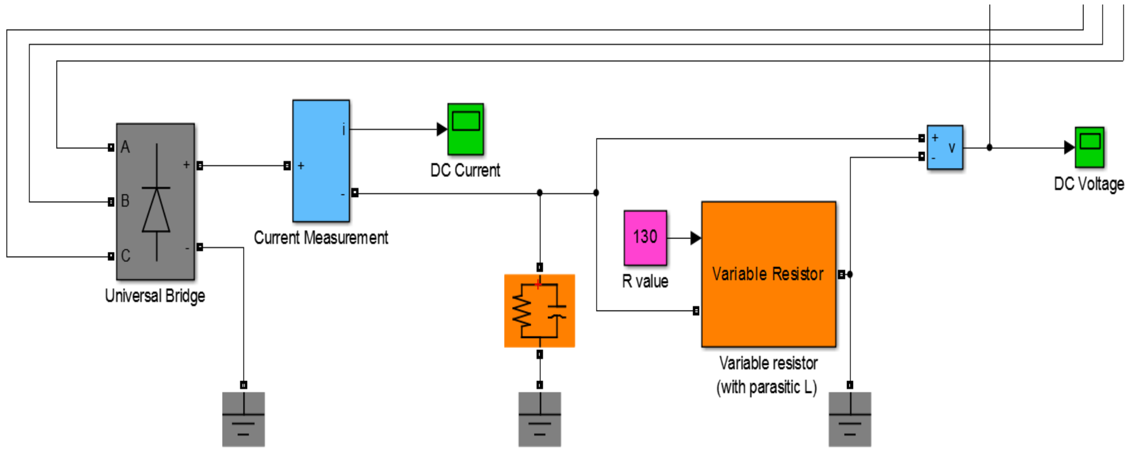

Figure 4.4: DC Convertor in simulink

4.5.3 Supercapacitor design

In figure 5.5 below a supercapacitors circuit is shown. Its charge through DC supply which is provided through DC converter which is given in figure 4.4. This stored power can be used for local purposes or it can deliver to grid system through smart grid system. We can also use batteries instead of supercapacitors.

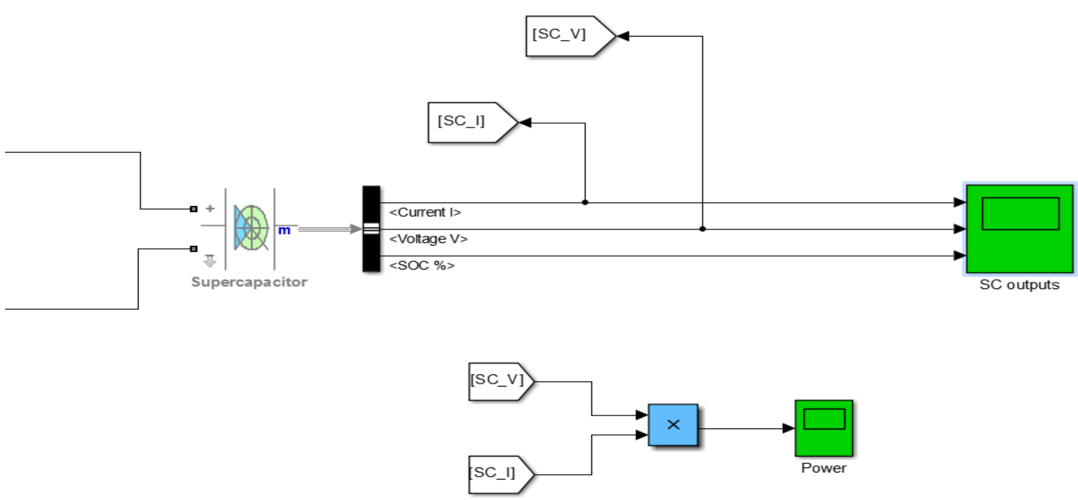

Figure 4.5: Supercapacitor in simulink

4.5.4 Smart Grid Design

In figure 4.6 below a smart grid circuit design of Matlab simulink is given, which is used to transmit extra power to national grid system.

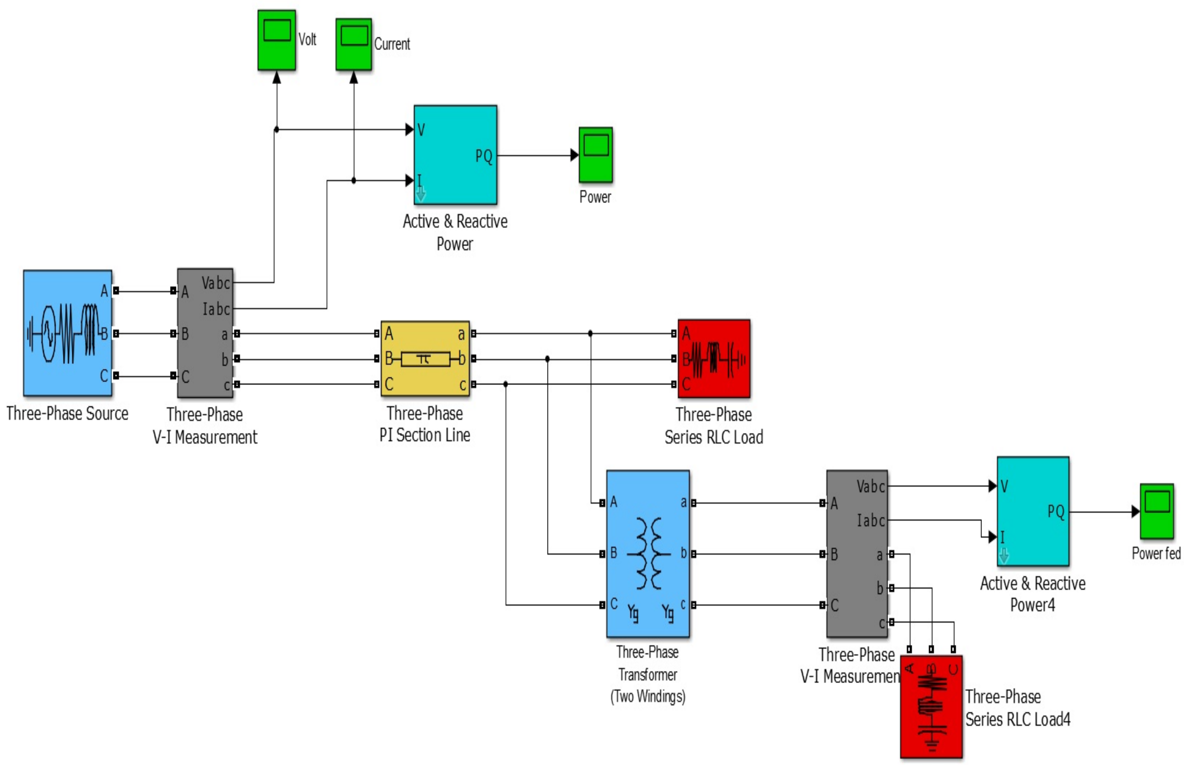

Figure 4.6: Smart grid design

4.6 Graphs

4.6.1 Relation between water flow and generated power

In figure 4.7 below a relation between water flow and generated power is shown. First, hydraulic power will be generated, after hydraulic power mechanical power will be generated. In graph, it can be seen it has low value than hydraulic power because power will be lose in Archimedes screw and gear box. Then, in next step electric power is generated which also depends on water flow and have some losses in generator.

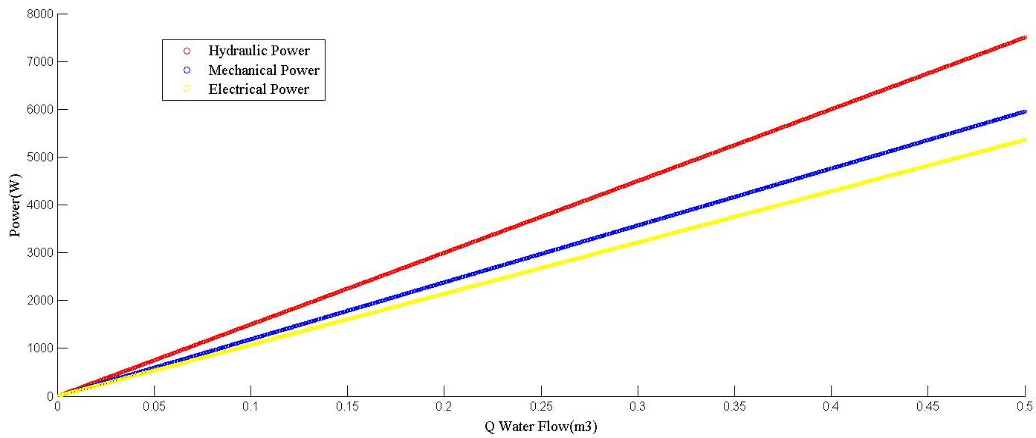

Figure 4.7: Relation between water flow and generated power

4.6.2 Relation between outer radius and inner radius

Figure 4.8 shows the relation of outer radius and inner radius of Archimedes screw and blades. Inner radius value depends on outer radius and it also depends on the value of ρ which is given in table.

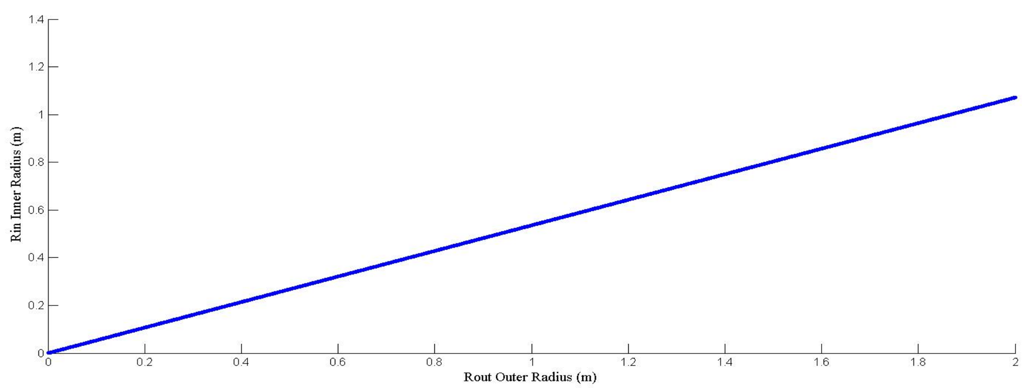

Figure 4.8: Relation between outer radius and inner radius

4.6.3 Relation between outer radius and volume

Figure 4.9 describes the relation of outer radius and volume of water carried by a screw.

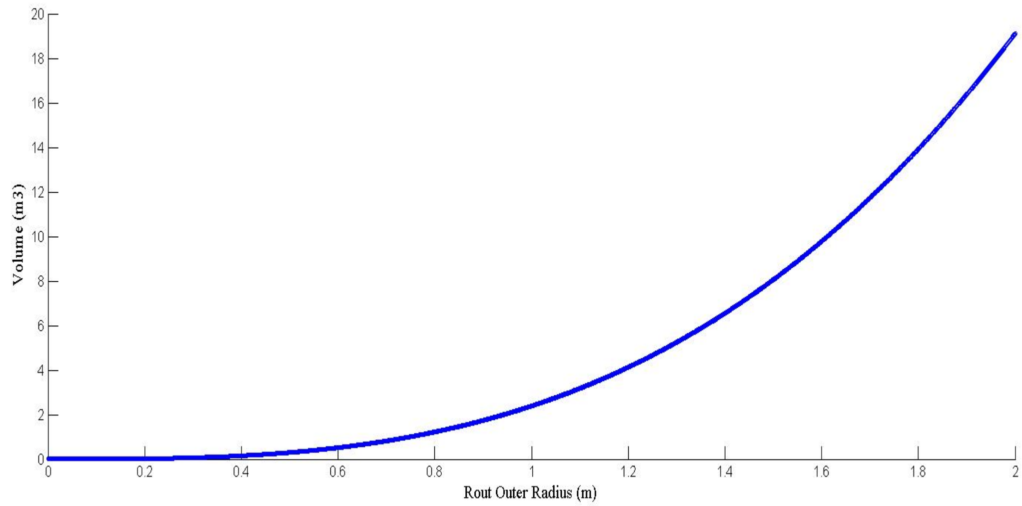

Figure 4.9: Relation between outer radius and volume

4.6.4 Relation between volume and mass of bucket

In figure 4.10 relation between volume and mass of bucket is shown. Mass of bucket directly depends on volume of bucket. Bucket is difference between blades of screw.

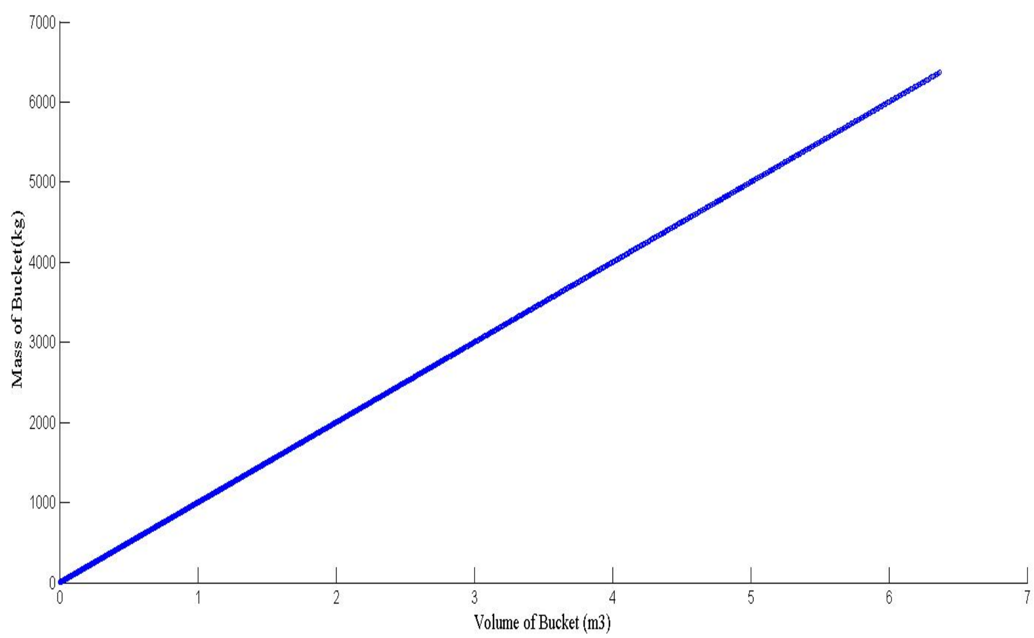

Figure 4.10: Relation between volume and mass of bucket

4.7 The Amount of Generated Electricity

From the results it was seen that value of generated power depends on water flow Q, head H, and the efficiency of turbine. Therefore it's noticed that Archimedes turbine gives high efficiency at low head. It gives efficiency 78% to 84%.

Below table shows generated electric power at different values of water flow and head. Generated power depends on efficiency of turbine and generator. It's also depends on water flow and head. Turbine efficiency can be improved be its better designing in better way. Efficiency also depends on number of blades N. Here in this table N= 3, and Electric generator efficiency is taken 90%. In table 4.1 different values are calculated by varying water flow and head.

Table 4.1: Generated electric power

P_e(Watt)	Water Flow(Q)				
Head	**0.01m^3/s**	**0.05m^3/s**	**0.1m^3/s**	**0.2m^3/s**	**0.5m^3/s**
.01m	.77	4.2	8.7	18	44
.05m	3.3	19	42	86	217
1m	45	254	570	1300	3631
2m	89.5	434	997	2311	6517
3m	142	670	1443	3258	9121

If this system is installed with a sewage system especially at outer flow side of treatment plants. So here we discussed two cases to have an idea that how much electric power is possible from sewage water. This produced power can be stored in batteries and also can be returned to sewage plant. If we have higher head available then it can be used stairs form.

Case 1

Here we can have water flow .01m^3 and head is 3 meter higher. Then generated electric power will be 142w.

Case 2

If the water flow is .5m^3 and head is selected 1 meter higher then electrical power will be 3631w.

4.8 Graphical Results

4.8.1 Generated phase voltages

In figure 4.11 we can see three graphs that represents generated electric voltages in each phase respectively V_a, V_b, V_c. 220 volts can be seen and frequency is 50Hz.

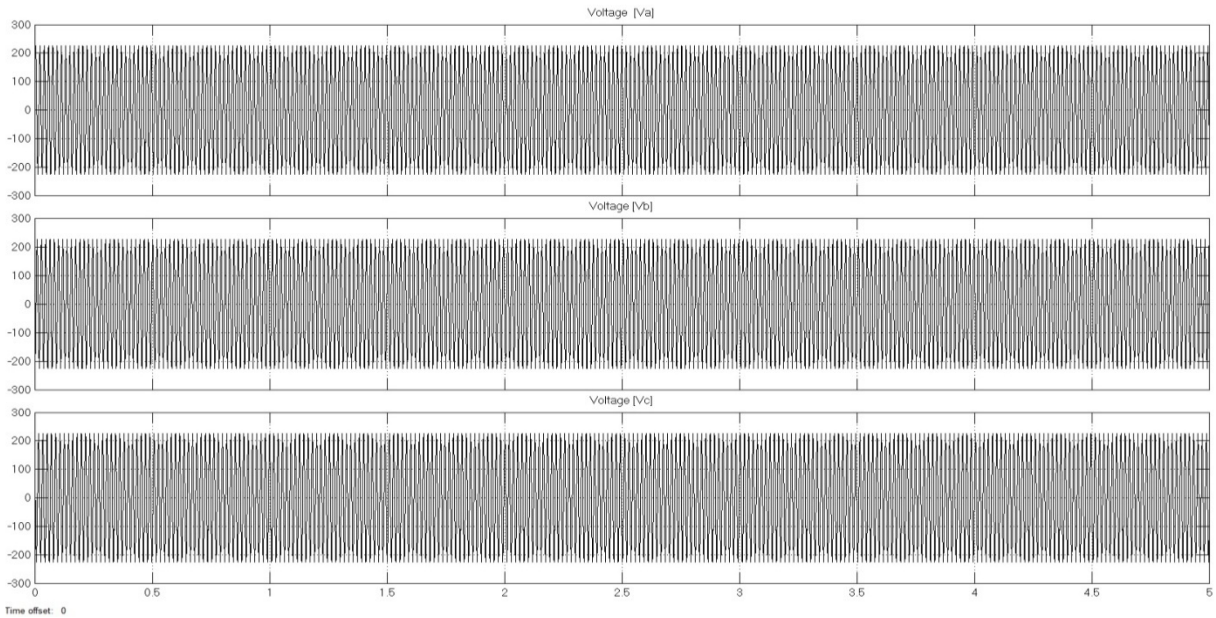

Figure 4.11: Generated phase voltages

In figure 4.12 below one cycle of volt of phase A is given.

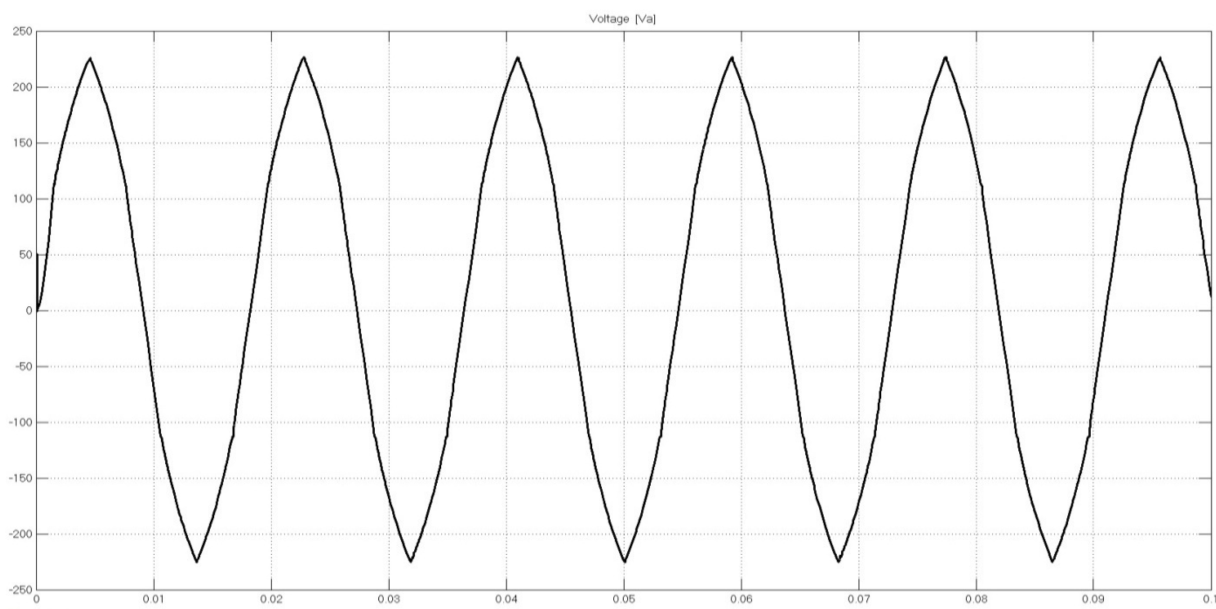

Figure 4.12: One cycle of AC volts

4.8.2 DC current

In figure 4.13 below graph shows the generated DC after rectifying AC power. It can be seen current it is 10 A.

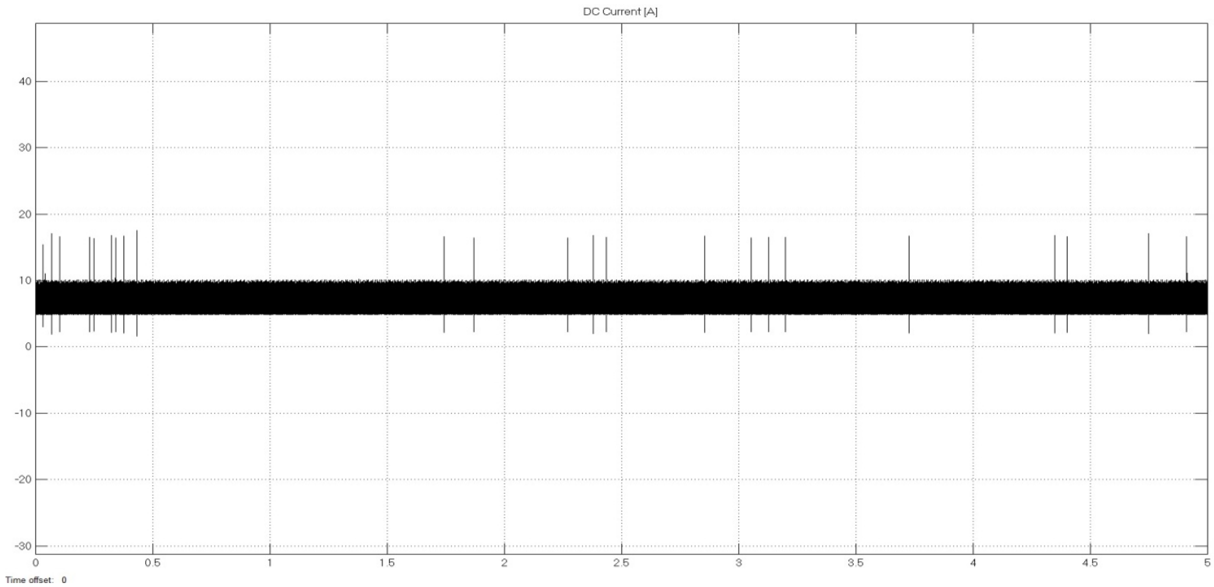

Figure 4.13: DC current

4.8.3 DC Volts

Figure 4.14 shows generated DC voltage. It can be seen it very good smoth shape wave and its value is 350 volts.

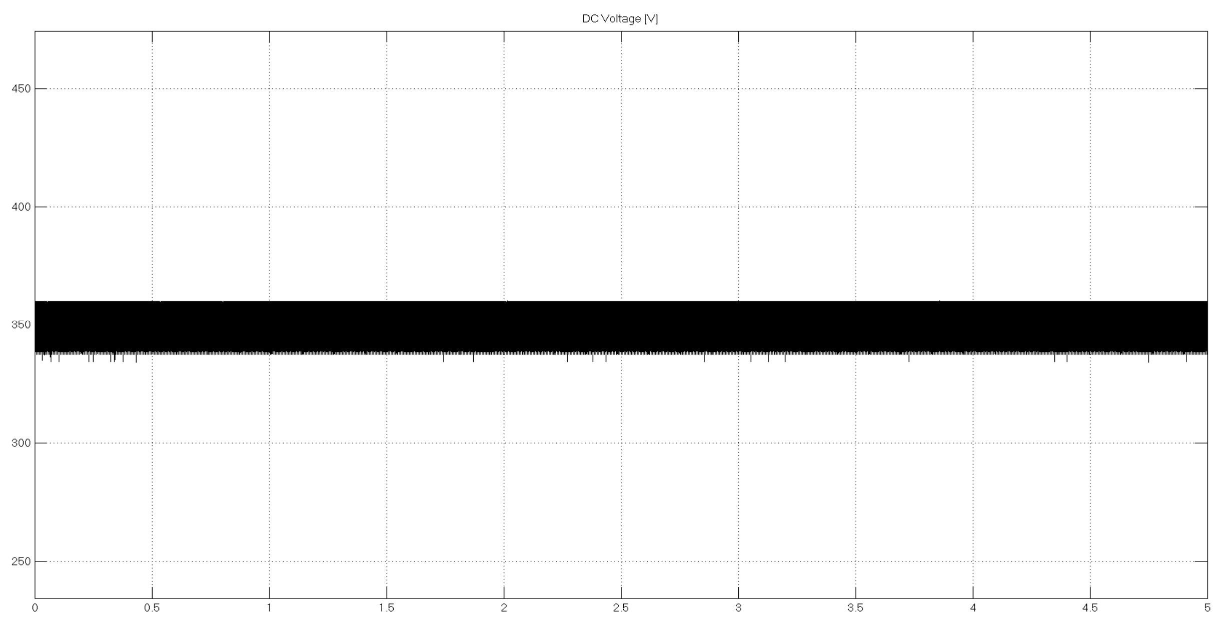

Figure 4.14: DC volts

4.8.4 AC and DC power

In figure 4.15 below generated AC power is shown. As it can be seen it is close to 3600 watt. It is according the expected calculations.

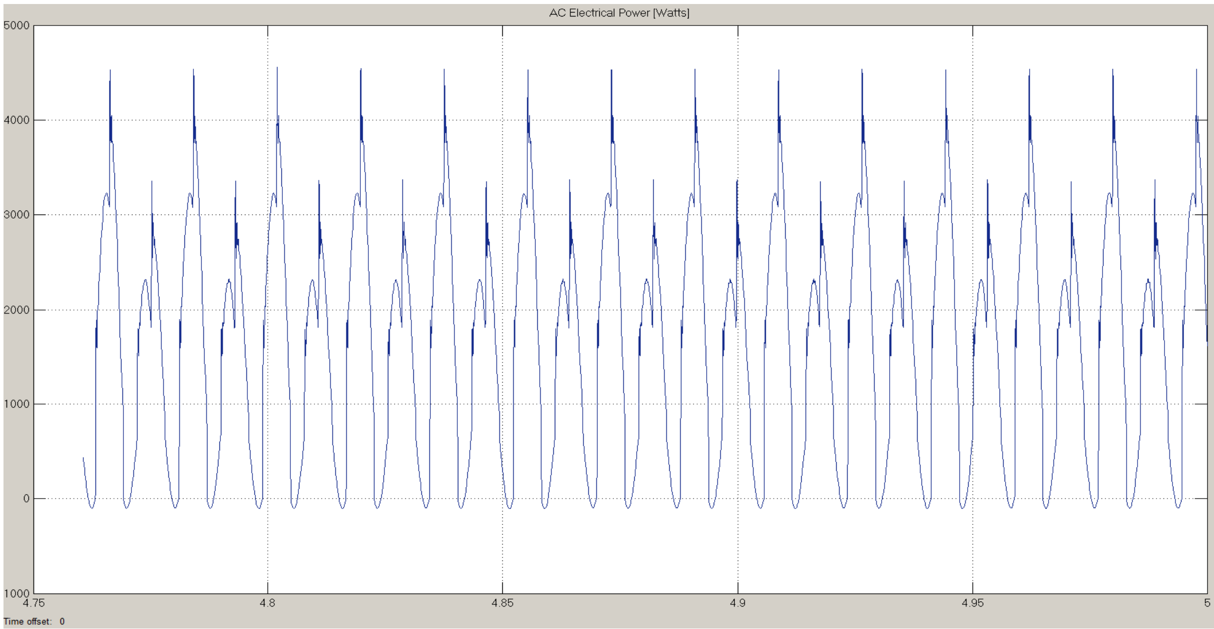

Figure 4.15: AC power

In figure 4.16 below DC power is shown, which shows there will be some power loss during AC to DC conversion.

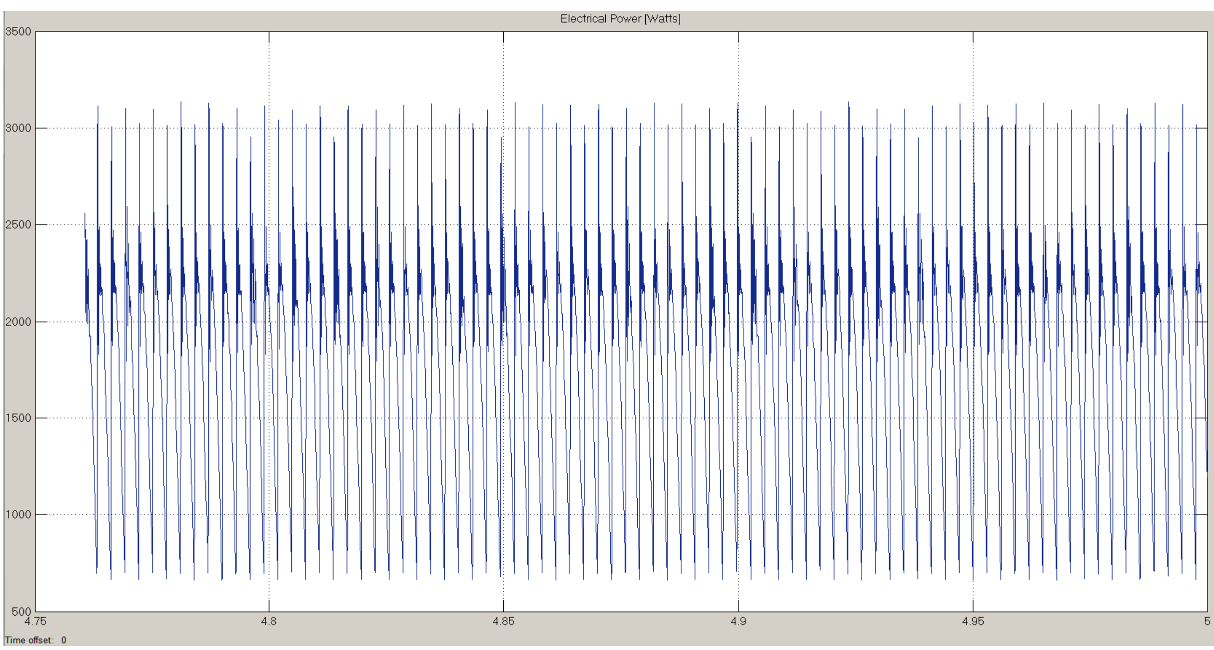

Figure 4.16: DC power

4.8.5 Hydaulic and mechanical power

Figure 4.17 shows the generated hydraulic and mechanical power. These power are generated at when the water flow was Q=.5m^3 and head was 1m higher.

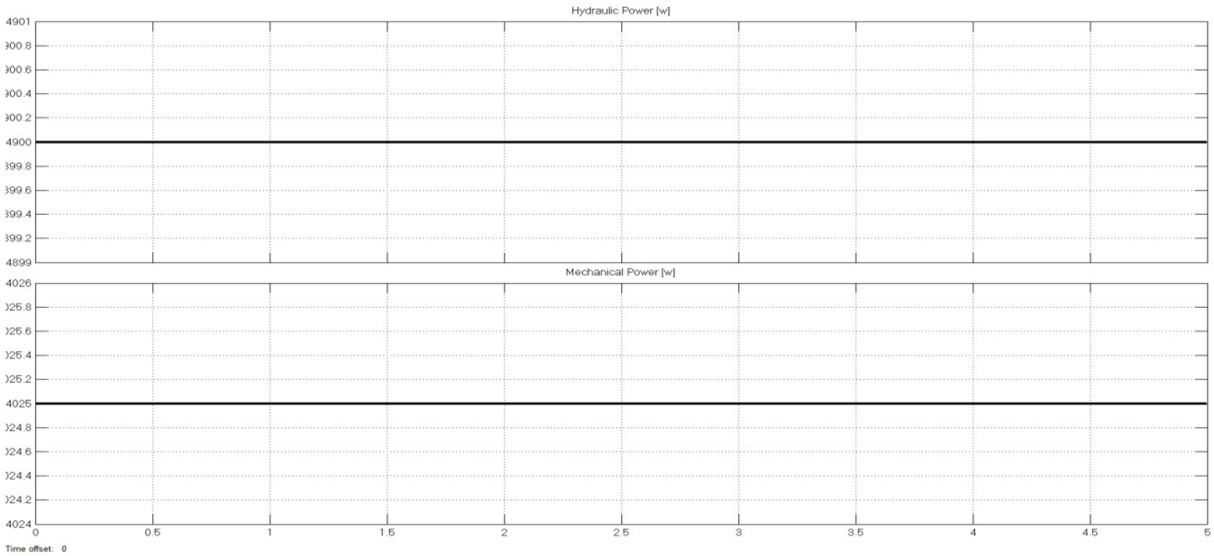

Figure 4.17: Hydraulic and mechanical power

4.8.6 Speed of screw and effecieny

Figure 4.18 shows screw efficiency 82% which is the reason to purpose this turbine and speed is 34.8.

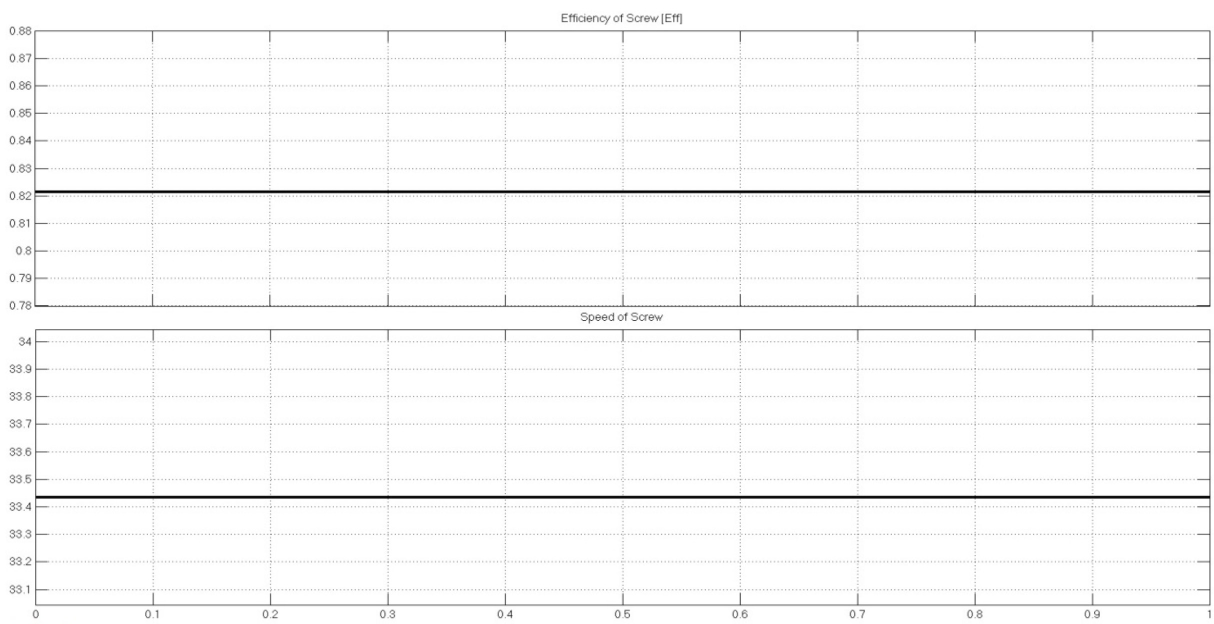

Figure 4.18: Speed of screw and effecieny

4.9 Discussion

In this work Archimedes screw was designed in matlab and then it was interfaced with a electrical design in simulink. Its noticed that generted power depends on the effeciency of screw. In figure 4.11, three phase AC voltages are shown. We can see it has good sinusoidal shape, 50 Hz frequency and 220 voltages for each phase. In figure 4.12 one cycle of each phase is shown. Figure 4.14 shows generated DC voltages, it can be seen that we have smooth shape of DC voltage. Because filter circuit is used in design to remove ripples. In electrical part as we can see in figure 4.15 we got three phase electric AC power. Which also has some losses appeared in generator and generated electric power is 3.6 kw. These losses depend on the efficiency of generator. Figure 4.16 shows generated DC power, this power comes from DC convertor. We use this DC convertor to store this power in supercapacitors for local use. Figure 4.17 shows the generated hydraulic and mechanical power. These power was generated at when the water flow was $Q=.5m^3$, number of blades $N=3$, and head was 1m higher. In figure 4.17 it can be seen that generated hydraulic power is higher than mechanical power. Because mechanical power comes after losses which occurs in Archimedes screw. These losses depend on the efficiency of Archimedes turbine. Here, in this thesis as we can see in figure 4.18 the efficiency of turbine is 82%, and this is the one main reason to use this Archimedes turbine. Because this turbine give high efficiency at low head. Number of turns are 34 so that is why gear box is used to synchronize this with a synchronous generator.

4.10 Comparison with Related Work

Here we compared our work with two papers first one we called gas generator presented in [3]. Second one is Erino Fiardi which was presented in [37].

4.10.1 Gas generator

In this purposed work they purposed the idea to use methane gas produces from the sewage water. There are different wastes produced by human beings, animals, plants. There are number of holes are used to reduce the pressure of gasses produced by a sewage in a sewage line. By blocking these holes and provide the outlets at some definite distances, the gas creates more pressure and we can utilize this pressure to rotate the prime mover of ac generator. Model shown in figure 4.19. Then we can get electricity from this process [3].

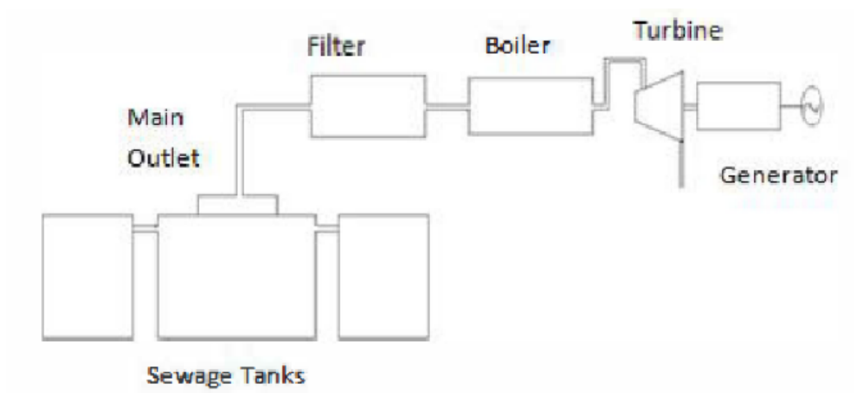

Figure 4.19: Sewage gas generator [3]

4.10.2 Drawback

But produce bio gas there should be animal wastes and agricultural waste. The main drawback of this purposed work is that there is no animal wastes and agriculture waste in cities. Therefore there is not enough methane gas available.

4.10.3 Erino Fiardi

In this work they designed a model of an Archimedes screw as a turbine. That screw has efficiency 49%. It had water flow Q=.00026m^3/s and inclination angle 45^o. It gives output power 0.098 watt [37].

According to our purposed designed this power can be increased if Inclination angle decreased from 45^o to 25^o, outer radius, and No of blades increased to N=3.

Table 4.2: Comparison with old paper

	Water flow	**Head**	**No of blades**	**Radius**	**Efficiency**	**Electric Power**
Erino	0.00026m^3/s	.125m	2	0.00126m	49%	0.098w
GESW	0.00026m^3/s	.125m	3	0.00526m	58%	0.131w

Table 4.2 shows a comparative view of both, upper row shows the measure data from paper [4]. Second row shows the values according to our design. Water flow level and head has same values. No of blades are increased and radius in increased. Therefore efficiency of screw increased from 49% to 58%. Electric power also increased from 0.098 watt to 0.131 watt.

4.11 Summary

In this chapter, all simulink designs, results and graphs were explained. Comparison with related work was also explained. For demonstration of the idea purposed in this thesis Matlab simulink is used.

CHAPTER FIVE
CONCLUSIONS

There were two main tasks in this thesis first was generate electricity by using waste water and second was to utilize that power. Therefore, Archimedes turbine was purposed for to use hydraulic power from sewage water and then this mechanical power is transferred into synchronous generator by using gearbox.

In second part DC convertor was used to AC power into DC power. Then supercapacitors were used to save that energy. In last part a smart grid circuit was used to connect this generated power with national grid system. Because there was no Archimedes screw in Matlab simulink so Archimedes screw was designed in Matlab simulink by using its geometrical values.

It is observed that the efficiency of screw depends on geometrical design, water head, water flow, and inclination angle. We get low flow rate and high efficiency with large inclination angle and small inclination angle gives high flow rate and low efficiency. But still efficiency of screw depends on designer.

The purposed model in this thesis can be used in urban areas where we have enough sewage and suitable geographical location. It can be more efficient if all sewage pipes are routed properly and waste water is collected and different high places. Then, this water used to rotate turbine. This kind of system can be designed in stairs steps form with suitable distance. Archimedes screw prospective is described for rural areas. A micro hydropower plant (MHP) is reliable energy source because of its erection on sewage plants which run throughout the year.

In second part of this diode bridge rectifier along with a supercapactors to store DC power. supercapacitors are like batteries, but have more good features than the batteries. Then it is also interfaced with a smart grid for efficient use of generated power. Because sewage water flow varies in all day.

5.1 Future Work

In future work a led street light system along with a sewage pipes can be designed which able to work with sewage flow.

This micro hydropower plant (MHP) also can be used along with the gas generator turbine by inclosing sewage pipes and using resultant methane gas.

Femto hydropower plants can be designed which works with water tank pipes and rain water from roof to ground pipes. They can charge small portable batteries or supercapacitors.

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