DESIGN AND DEVELOPMENT OF AN INTEGRATED CONTROL OF REAL TIME DATA MONITORING FOR REMOTELY LOCATED SYSTEMS

A thesis submitted to the
University of Petroleum and Energy Studies

For the Award of
Doctor of Philosophy
in
Electrical and Electronics Engineering

BY
NARENDRA BALKISHAN SONI

November 2019

Supervisor(s)
Dr. Kamal Bansal
Dr. Devender Kumar Saini

UPES
UNIVERSITY WITH A PURPOSE

Department of Electrical and Electronics Engineering
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DECLARATION

I declare that the thesis entitled "**Design and Development of an Integrated Control of Real Time Data Monitoring for Remotely Located Systems**" has been prepared by me under the supervision of Dr.Kamal Bansal, Professor of Electrical & Electronics Engineering, UPES & Dr. Devender Kumar Saini, Assistant Professor (SG) of Electrical & Electronics Engineering, UPES. No part of this thesis has formed the basis for the award of any degree or fellowship previously.

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CERTIFICATE

I certify that Narendra Balkishan Soni has prepared his thesis entitled **"Design and Development of an Integrated Control of Real Time Data Monitoring for Remotely Located Systems",** for the award of PhD degree of the University of Petroleum & Energy Studies, under our supervision. He has carried out the work at the Department of Electrical & Electronics Engineering, University of Petroleum & Energy Studies.

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ABSTRACT

Millions of years earlier, the Earth was formed and then came the first life forms followed by evolution, and then evolution reached the current pinnacle, Homo sapiens. From the start, we have always worked towards our betterment and enhancing our livelihood. In the stone age, we built tools and weapons out of stone to help us hunt and gather food better. Discovery of fire and the ways to use it brought about revolutionary changes in the way that we lived. Invention of potter wheel during Bronze age brought the revolutionary changes in livelihood. The invention of wheel, during Copper age has truly turned wheel of human fortune. The invention of the wheel has helped in agriculture, transportation that effected in settling down and growing food to meet the increasing demand.

This was followed by the Industrial Revolution! During 16^{th} century researcher like James Watt have rotated wheels by steam power, showcased application of mechanical energy to rotate wheels and then Faraday, invented electricity. Since the electricity was generated, the humankind has started using electrical energy in part of life then it has become an integral part of one‘s day to day life and the leading cause of all the developments and innovations that we see today and are going to see in the future.

Electricity can be practically described as our ‘fourth‘ basic need after food, clothes, and shelter. The main cause for this is that electrical energy is easy to control and convert for our benefit. Our livelihood is almost completely depend on electricity and it is shuddering to think of life without electricity.

Globally, human beings have spread their wings, be it Arctic region or Antarctica! The technological developments are also growing at an exponential rate. This development has made human life sophisticated and luxurious. With widespread livelihood across billions kilometers of area and extreme variations in geography, it is challenging to create a real technological developments to every individuals, specifically for the people living in remote areas. The people living in these areas have actually truly ’remote’ in most of respect from the rest of fast developing world.

While there is a clear necessity for networks that supports reliable technology transfer

to ease the livelihood of the remote location people, there are many problems related to accessibility, performance, suitability, sustainability and working of the inter connected paths that need to be resolved. The focus would be on recognizing the available infrastructure with cost effective technologies in order to fulfill the work. Optimization techniques and the right implementation of communication protocols would be helpful in the designing good and reliable network that quality of service to power accessibility applications. The optimization would be also helpful to manage the access points in the smooth power flows among the users and network. The analytical and simulation tools would foster the development of new areas of inquiry into specific communication technologies that links different power points.

To accelerate the development of reliable, cost effective and secure communications standards for this work, and to enable well-versed decision making by communication operators optimization technique would be a dependable solution in the network connecting end users.

By deploying measurement values and choosing the right communication technology is very critical to define the success of each utility. It requires a thorough consideration across all assessment criteria. There is no one-size fits-all solution because each technology has its own limitations and it can be the best solution for different problem.

Motivation

Electricity, one of the basic need of modern world, has not reached to all mankind on the earth! There is are various reasons for the same and one of the major is remote location. Due to far off remote locations, extreme geographical conditions, interruptions due to disasters etc. many technological developments have not reached every human being and electricity being one of them! In India many villages, which are occupied by millions of people are still without electricity. Some of the reasons for this are

1. They are located at far off locations
2. There is geographical complexity to install transmission lines/distribution lines to these villages.
3. It is economically and technologically not feasible to extend transmission lines to these villages
4. There are environmental threats in extending transmission lines to such remote locations.

Various solutions have been tried so far to provide electricity to these villages. With the developments in renewable energy, particularly solar and wind electrical, supply to these villages / locations seems possible. The renewable energy sources like solar, wind, biomass (locally available), micro / pico hydro etc. are indigenous in nature and depends on the naturally available sources like Sun energy, Wind energy, forests, potential energy of water etc. Such energy sources are abundant in nature and are available in every part of the Earth. There are no constrains which can stop its availability / usage.

Efforts were made to provide electricity by installing micro size 'power plants' using these naturally available sources and to provide an access of electricity to these villages.

There were difficulties in installing power plants like transportation of equipment due to extreme geographic locations. However, as the installation is a onetime activity, extensive efforts were made to transport the equipment and power plants were installed constructed. The necessary grids were constructed and access to electricity was provided to the local habitats. Also, after having installed power plants, local habitats were provided with training for regular maintenance and minor troubleshooting so that, continuity in supply of electricity can be maintained.
The livelihood of the village residents was improved and cheers on the faces were discovered.

But the cheer was not long lasting, as over a period of time power plants started facing technical problems which were beyond repairable by local habitats. The expert technical assistant could not be provided due to difficulty in access and lack of communication. As a result the Power Plants started getting deteriorated and are finally stopped functioning. In short *the provision of micro power plants at remote location has not provided a permanent solution to access electricity.*

The major reason for failure of these power plants was lack of appropriate action at appropriate time! The local habitats are good for routine maintenance and minor troubleshooting. With their limited knowledge and understanding the major issues associated with power plants cannot be rectified. In case if there is any issue which is beyond the knowledge of local habitats, the desired troubleshoots could not be done and as a result the system started malfunctioning. The technical expert could not take any action as he was unaware of the situation at remote location. Thus, due to the difficulty in timely identification of problem and appropriate troubleshoot the 'Power Plants' started getting further deteriorated.

This situation has persisted with most of remotely located systems and any further and further deterioration in power systems resulted in to these power systems becomes inoperative and failed to serve the desired purpose. If the technical expert is able to take appropriate corrective measures at the first instant, the situation would have been different and these systems then would have served the desired purpose for a longer duration.

As the locations are very remote, it is practically very difficult for technical expert also to visit and access the health of the Power systems on regular basis. However, if any provision is made such that the expert can access the related parameters of the ‘Power Plants’ from a distance location and in case if any abnormal behavior is observed then the expert can take the required corrective measure to ensure the proper operation of the ‘Power Plants‘. Such timely corrective measures will also prevent any further deterioration of power plant and thus the long term operation can be ensured.

The outcome of the discussion is that, ***To ensure the sustainable solution for improving the livelihood of remotely located village, it is required to provide the ‘technological systems’ for these villages, along with a mechanism to ensure proper operation and maintenance of these systems.***

By knowing the values of the various operational parameters of the power plant, we can analyses about the proper functioning of that power plant. The knowledge of various parameters can be easily gathered with the help of basic measurement and instrumentation techniques.

This heath analysis of the power plant will be more realistic and effective if the information related to various operating parameters of the system is gathered on real time basis. With the help of various sensors, all required parameters of the system can be easily measured and observed. These various parameters can be communicated to the real time monitoring system through wired communication network. As long as the ‘system’ and ‘monitoring system’ are in vicinity, wired communication network can be adopted. However, if the systems are distinctly located but within ‘communicable’ then also they can be communicated to each other through various ‘wireless’ communication techniques like CDMA/ GSM / Internet etc.

Based on above discussion, it can be concluded that, if the remotely located power systems are within accessible range or at least in communicable range, the technology is available that could provide power for the longer period without much difficulty.

In reality, there are many locations which are neither easily accessible nor are within communicable range and hence uninterrupted ‘power to all’ over a long period looks impractical.

In this research work it is proposed to provide a solution for the real time monitoring of parameters for remotely located power system. It is proposed that the data from the various remotely located power system systems will be communicated with the help of ‘localized communication network’ up to a location where GSM or CDMA network is available.

Localized communication network can be developed using the communication technologies like Bluetooth, WIBER, IR communication, ZigBee etc. There communication technologies can be easily used to communicate data without involvement of network provider or complex network. Hence the real time measured data from the power system can be transferred from one point to other point with these technologies even though ‘no network provider‘ is available. However, the usage of these technologies is limited over a small distance and other limitations include slow rate of data transmission, limited range of data samples, loss of data due to geographical constrains etc.

Thus if we have to use these technologies, we have to find a solution on these issues. The issue of ‘limitation of data communication’ can be resolved by using the series/chain of such localized communication network. The data from a remotely located power system can be transmitted from one point to other point and to further points using multiple devices till data is reached to a location where GSM/CDMA network is available. Once the localized communication ‘transmits’ data to GSM network, then this data can be globalized and this data that the real time parameters of a remotely monitored power system can be monitored, analyzed and appropriate action can be taken as required.

But as the ‘remotely located power system‘ can really be many kilometers away from the nearest GSM/CDMA network, the series of ‘localized communicating‘ devises can be very long and large. Each device need to provide with uninterrupted ‘energy‘. Thus practically it becomes very complex and complicated. However, there is no alternative.

Since we have no alternative than to provide the localized communication network, in this proposal it is proposed that with help of optimization techniques with can at least optimize the size and count of localized communicating devices and thus there is reduction in ‘practical difficulties.

Thus in this proposal an optimized solution with integration of communication technologies for the real time monitoring of remotely located power system is provided.

The orientation of this thesis is briefly outlined as follows. chapter 1, gives details of various existing remotely located power systems like Solar, Micro Hydro, wind etc and also the locations of some of the plants. The chapter describes their status in terms of working condition, their designed rating, their present performance, the probable reasons for their under-performance or being not in working condition etc. The chapter describes the proposed topic and the methodology of the proposal. The chapter describes the various monitoring parameters that are to be assessed to ensure the healthiness of the remotely located power systems.

The chapter gives the brief of various technology used for the purpose of data communication. The comparison of various technologies has been also being given in the chapter. In short the chapter describes the problem.

Chapter 2 gives the brief description of literature survey that has been referred for the research proposal and problem findings. The various research papers, research articles, book chapters have been studied to arrive at the problem and designated solution.

Chapter 3 : This chapter describes algorithm for optimization. During problem formation it was also identified that, as the remotely located power systems are far away, there are requirement integration of many wireless gadgets. Each gadgets (node) shall require investment, maintenance, electric power etc. Also, as the number of devices increases, the complexity of problem also increases. Hence, is proposed to optimize the path for data transmission. Also, the remotely located systems, may exists at geographically complex locations (like mountains etc), it was required to optimize the path taking in to all considerations like geographical complexity etc.

Optimization techniques and Haversine formula are used to define the optimized path with no geographical complexity. A practical and real time case study of four remotely Villages in state of Uttarakhand has been discussed and the optimized geographical coordinates (GPS coordinates) have been identified for the placement of ZigBee(s). In short, the chapter describes the Optimization algorithm for the various purpose required for the research proposal.

Chapter 4, the proposed research proposal has hardware design and then integrated with software coding. This chapter describes the design of hardware for sensing the parameters like voltage, current, flow rate, solar insolation, temperature, water quality etc and software coding for the integration of same. With the help of signal conditioning circuit, the sensed data is processed and converted in digital form. This data is then transmitted using WLAN over a distance where global network is not available. This data is transmitted with integration of various wireless networking techniques like ZigBee, Bluetooth till the location where global signals (GSM/CDMA) are available. Then with the help of global network this data is received at the desired location. At the desired location (control room) this data is received, process and displayed for the operator. In short, the chapter describes about the hardware design and software coding for integration of hardware for the research proposal.

Conclusion of the research work, practical limitations and fFuture scope has been discussed in Chapter 5.

The result of this research work can be concluded that, with help of modern technology and renewable energy, the ‘distance‘ between remotely located villages and ‘popular‘ locations like cities can be reduced and we can help the underprivileged society to be the part of main stream. The research work also provides an optimized solution for this Nobel cause, that not only helps in reducing initial investment but also reduces the complexity thus reduces the operational and maintenance cost and also improves the system reliability. With the help of this research work, the villagers can also have access to modern education, healthcare, latest information, disaster warnings etc. In nutshell, this research work is an attempt to help the underprivileged society and to help in nation building.

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Date: 14 November 2019 Narendra B Soni (500031719)

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NOMENCLATURE

Abbreviation	Acronym
4G-LTE	4th Generation Long Term Evolution
BU / MU	Billion Units / Million Units
DAC	Data Acquisition Card
DMCI	Data Monitoring Control Interface
EMS	Energy Management System
FPGA	Field Programmed Gated Array
GA	Genetic Algorithm
GIS	Geographical Information System
GPS	Global Positioning System
GPRS	Global Positioning Radio System
GSM	Global System for Mobile
GUI	Graphical User Interface
IED	Intelligent Electronic Devices
IIoT	Industrial Internet of Things
IoT	Internet of Things
ISIS	Intelligent Schematic Input System
kWP	Kilo Watt Peak
LAN	Local Area Network
LBS	Location Based Service
LVRT	Low Voltage Ride Through
MD	Maximum Demand
NE	North East
OFC	Optical Fiber Communication
PMU	Phasor Measurement Unit
PSO	Particle Swarm Optimization
PV Cell	Photovoltaic Cell
PWM	Pulse Width Modulation
RES	Renewable Energy Sources
RoI	Return on Investment
RTDM	Real Time Data Monitoring
RTDMS	Real Time Data Management System

RTS	Real Time System
RTU	Remote Terminal Unit
RTOS	Real Time Operating System
SHP/MHP	Small Hydro Power plant/Micro Hydro Power plant
SIM	Subscriber Identity Module
SPI	Serial Peripheral Interface
SPP	Solar Power Plant
SPV	Solar Photovoltaic
SSR	Solid State Relay
USART	Universal Synchronous Asynchronous Receiver Transmitter
USB	Universal Serial Bus
VISA	Virtual Instrument Software Architecture
VSM	Virtual System Modeling
WAN	Wide Area Network
WLAN	Wireless Local Area Network
WSN	Wireless Sensor Network

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CHAPTER 1

INTRODUCTION

Electricity is, by all means, the best invention and a very important blessing from Science has given to the mankind, without which we cannot even imagine the world today, and it is impossible to even understand the importance of role played by it in today‘s development. The grandeur of it can be seen by that we measure the standard of living of people living in a country by the per capita consumption of electrical energy. Due to the advancement in science and technology, it is now very easy to convert one form of energy into another and fortunately, electrical energy is the most easy to convert.

All the above clearly show how important electrical energy has been shaping forth the ‘unimaginable future’ that we live in today.

1.1 ENERGY VISION AND POWER SCENARIO

Electrical energy is secondary source of energy and it can be produced by converting some form of primary energy in to electrical energy. Primary Energy sources like coal, oil, gas, Solar, wind, etc. is converted in to electrical energy. The industries, where the one form of energy is converted in to electrical energy is called as power plants. Each country is expected to have sufficient power generation capacity.

Even with all the developments, we still have many issues and limitations in efficiently harnessing the electrical energy. One such and a major problem is availability, especially in developing countries like India- there is a huge gap between demand and supply, and this imbalance results in load shedding, sometimes even for many hours, in many parts of the country. As of Oct 31, 2018, India’s total installed capacity is 3,46,047.59 MW. The details of installed generation capacity are given in Table 1.1[1,2].

In comparison to most of the countries, India is at the 3^{rd} position (Table 1.2) [3,4] with respect to generation of electrical power.

The source wise, power generation for last 4 decade is shown in Table 1.3[4], which indicates that, power generation capacity has increased multi fold in last decades. Though India is world‘s 3^{rd} highest power producer, but Per capita consumption (which is direly defines livelihood) is concerned, India is among last few, as shown in Table 1.4[5].

Table 1.1: India‘s installed power generation capacity (as of 31.10.2018)[1,2]

	Thermal								
Region	Ownership	Coal	Gas	Diesel	Total	Nuclear	Hydro	RES	G.Total
Northern	State	15934	2879.2	0	18813.2	0	8697.55	689.56	28200.31
Northern	Private	22760.83	558	0	23318.83	0	2514	12615.35	38448.18
Northern	Central	12585.37	2344.06	0	14929.43	1620	8496.22	329	25374.65
Northern	Sub-Total	51280.2	5781.26	0	57061.46	1620	19707.77	13633.91	92023.14
Western	State	21280	2849.82	0	24129.82	0	5446.5	311.19	29887.51
Western	Private	34885.67	4676	0	39561.67	0	481	20051.7	60094.37
Western	Central	15042.95	3280.67	0	18323.62	1840	1620	661.3	22444.92
Western	Sub-Total	71208.62	10806.49	0	82015.11	1840	7547.5	21024.19	112426.8
Southern	State	19432.5	791.98	287.88	20512.36	0	11838.03	521.02	32871.41
Southern	Private	12124.5	5322.1	473.7	17920.3	0	0	34958.15	52878.45
Southern	Central	14225.02	359.58	0	14584.6	3320	0	491.9	18396.5
Southern	Sub-Total	45782.02	6473.66	761.58	53017.26	3320	11838.03	35971.07	104146.36
Eastern	State	6950	100	0	7050	0	3537.92	225.11	10813.03
Eastern	Private	6375	0	0	6375	0	399	848.53	7622.53
Eastern	Central	13876.64	0	0	13876.64	0	1005.2	10	14891.84
Eastern	Sub-Total	27201.64	100	0	27301.64	0	4942.12	1083.64	33327.4
NE	State	0	497.71	36	533.71	0	422	256.74	1212.45
NE	Private	0	24.5	0	24.5	0	0	25.71	50.21
NE	Central	520.02	1253.6	0	1773.62	0	1030	5	2808.62
NE	Sub-Total	520.02	1775.81	36	2331.83	0	1452	287.45	4071.28
Islands	State	0	0	0	0	0	0	5.25	5.25
Islands	Private	0	0	0	0	0	0	2.21	2.21
Islands	Central	0	0	40.05	40.05	0	0	5.1	45.15
Islands	Sub-Total	0	0	40.05	40.05	0	0	12.56	52.61
All India	State	63596.5	7118.71	323.88	71039.09	0	29942	2008.87	102989.96
All India	Private	76146	10580.6	473.7	87200.3	0	3394	68501.65	159095.95
All India	Central	56250	7237.91	40.05	63527.96	6780	12151.42	1502.3	83961.68
All India	**Sub-Total**	**195992.5**	**24937.22**	**837.63**	**221767.4**	**6780**	**45487.42**	**72012.82**	**346047.59**

Courtesy: Ministry of Power

We can clearly see that even though the country has sufficient installed capacity for the power generation, the peak power is seldom reached (Table 1.5)[4].

Another major issue is the availability of ‘Power to all’. In India approximately 44% rural population suffer from unreliable electricity supply, which extensively affects education, income generation, and access to information, and also hinders productive activities, sustainable development, and livelihood [6-9].

Due to this gap between demand and supply and many other constraint electrical power has not been able to reach all the people. In India, many villages are still un-electrified resulting in millions of Indians to have to live in candlelight!

Status of house hold electrification and rural electrification in India is given in Table 1.6 and Table 1.7.

The Government of India has a visionary mission of ‘Power to all’ and ‘Electrification of all un-electrified villages’ by 2020, but there are many constraint that need to be solved to meet this ambitious vision. One of the issues is connecting many of the villages to the national grid- being remotely located; they are far off from main power grid. These villages are so far off from national grid that, both economically and geographically, it

Table 1.2: Country wise electrical energy generation[3]

Country	Energy Generation in BU
China	6,142
United States	4,088
India	**1,289**
Russia	1,008
Japan	976.3
Canada	643.2
Germany	588.5
Brazil	559.2
France	536.1
Korea, South	528.1
Saudi Arabia	318
United Kingdom	309.8

Courtesy: https://qz.com/india/1237203/india-is-now-the-worlds-third-largest-electricity-producer/

Table 1.3: Annual gross generation of power by sources in India[4]

(1980-1981, 1985-1986 and 1990-1991 to 2017-2018) (in MU)							
Years	Hydro	Steam	Diesel&Wind	Gas	Nuclear	Thermal	Total
1980-1981	46541.8	60713.8	61.5	522	3001.3	-	110840.4
1985-1986	51020.6	112540.1	50.6	1756.9	4981.9	-	170350.1
1990-1991	71641.3	178321.7	111.3	8113.2	6141.1	-	264328.6
1991-1992	72757.1	197163.2	134	11450	5524.4	-	287028.7
1992-1993	69869.2	211123.5	162.3	13480.4	6726.3	-	301361.7
1993-1994	70462.7	233150.7	310.9	14727.6	5397.7	-	324049.6
1994-1995	82712	243110.2	545.2	18474.8	5648.2	-	350490.4
1995-1996	72759.2	273743.5	714.4	24858.4	7981.7	-	380057.2
1996-1997	68900.8	289378.3	1554.3	26984.9	9071.1	-	395889.4
1997-1998	74581.7	300730.5	1929.3	34423.2	10082.6	-	421747.3
1998-1999	82690	308056	2136	43480	12015	353662	448367
1999-2000	80637	377814	3989	49773	13267	386776	480680
2000-2001	74481	357006	3822	48311	16928	408139	499548
2001-2002	73579.9	370883.5	6402.7	47098.6	19474.6	424385.8	517439.2
2002-2003	64014	389550.3	7052.4	52686.6	19390	449289.3	532693.3
2003-2004	75242.5	407283.8	6867	57928.4	17780	472079.2	565101.7
2004-2005	84495.3	424083.2	2518.7	59473.6	16845.3	486075.5	587416.1
2005-2006	103057.3	435096.6	1987.7	60128	17238.9	497214.3	617510.4
2006-2007	116368.9	461340	2488.8	63718.6	18606.8	527547.4	662523
2007-2008	128702.1	486763.2	3297.3	68930.6	16776.9	558990.1	704469
2008-2009	118980.7	512527.1	4708.6	72865.1	14712.6	590100.8	723793.6
2009-2010	112038.2	539982.4	4243.4	96650.6	18636.4	640876.5	771551.1
2010-2011	119868.3	561757	2993.9	100257.2	26266.4	665008.1	811142.8
2011-2012	135794	612880.2	2461.3	93464.4	32286.6	708805.9	876886.5
2012-2013	118514.7	691555.1	2284.7	66835.9	32866.1	760715.8	912056.7
2013-2014	140445.4	746086.7	1868.2	44522.2	34227.8	792477.1	967150.3
2014-2015	129243.7	835290.8	1576.7	41075.5	36101.5	73563.2	1116849.9
2015-2016	121376.7	895339.8	551	47122.1	37413.6	65780.8	1167584
2017-2018	-	-	-	-	-	857923.14	-

Courtesy: Indiastat

Table 1.4: Global per capita consumption[5]

Country	Consumption in MWh
Iceland	53.91
Norway	23.69
Bahrain	19.51
Qatar	15.48
Finland	15.47
Kuwait	15.28
Canada	14.84
Luxembourg	14.27
Sweden	13.76
United States	12.83
Chinese Taipei	10.88
Korea	10.62
Australia	9.91
Japan	7.97
China	4.28
India	**0.92**
Ethopia	0.09
Sudan	0.03

Courtesy: World Bank

is not feasible to carry the 'Electrical Lines' from national grid to these villages. Hence, the electrification of these villages has always remained a challenge. Government of India has made efforts to electrify some of these villages (Table 1.6) with the help of renewable energy.

1.2 RENEWABLE ENERGY AND ELECTRIFICATION OF REMOTELY LOCATED VILLAGES

This problem of 'reach of electrical power' from national grid can be easily overcome with the help of renewable energy. With the overflowing research in renewable Energy, it is now easy to set up renewable energy based power plants and then distribute the electrical power throughout the village. power plants like Solar power plant and Wind power plants can be installed to meet the power requirement of the village[8,9]. Though these power plants are set up to meet the demand, their performance is not guaranteed and, in many cases, these plants are either obsolete or underrated, thus defeating the cause. Lifetime performance of these installations can be ensured if there are provisions for monitoring the conditions of these installations.[10,11].

Table 1.5: Power supply position (peak demand and peak met) in India[4]

Power supply position (peak demand and peak met) in India (1996-1997 to 2018-2019-to September 2018) in MW				
Year	Peak Demand	Peak Met	Shortage	Shortage in Percentage
1996-1997	63853	52376	11477	17.9741
1997-1998	65435	58042	7393	11.29823
1998-1999	67905	58445	9460	13.93123
1999-2000	72669	63691	8978	12.35465
2000-2001	78037	67880	10157	13.01562
2001-2002	78441	69189	9252	11.79485
2002-2003	81492	71547	9945	12.20365
2003-2004	84574	75066	9508	11.24223
2004-2005	87906	77652	10254	11.66473
2005-2006	93255	81792	11463	12.2921
2006-2007	100715	86818	13897	13.79834
2007-2008	108866	90793	18073	16.60114
2008-2009	109809	96785	13024	11.86059
2009-2010	119166	104009	15157	12.71923
2010-2011	122287	110256	12031	9.838331
2011-2012	130006	116191	13815	10.62643
2012-2013	135453	123294	12159	8.976545
2013-2014	135918	129815	6103	4.490207
2014-2015	148166	141160	7006	4.72848
2015-2016	153366	148463	4903	3.196928
2016-2017	159542	156934	2608	1.634679
2017-2018	164066	160752	3314	2.019919
2018-2019*	176538	175528	1010	0.572115

Courtesy: Indiastat

Table 1.6: House hold electrification Status (Oct 10, 2017)[7]

State	Total	Electrified	Un-electrified	% Un Electrified
Odisha	2451154	2072861	378293	15.43326
J&K	1855669	1842778	12891	0.694682
HP	3693061	3689584	3477	0.09415
PJB	2076613	1844305	232308	11.18687
UK	3469972	3415291	54681	1.575834
Harayana	28675462	21196195	7479267	26.08246
UP	12598991	10895915	1703076	13.51756
Rajasthan	11414532	11373215	41317	0.361968
Gujrat	12621007	10636743	1984264	15.72192
MP	13973122	10714081	3259041	23.32364
Bihar	98768	83868	14900	15.08586
Sikkim	302361	255272	47089	15.57377
Arunachal	6966079	5357458	1608621	23.0922
Assam	523870	391363	132507	25.29387
Nagaland	453142	350925	102217	22.55739
Manipur	241796	213909	27887	11.53328
Mizoram	788871	652463	136408	17.29155
Tripura	635802	435963	199839	31.43101
Meghalaya	15058530	14326240	732290	4.862958
WB	6749036	5366642	1382394	20.48284
Jharkhand	9621296	7219409	2401887	24.96428
CG	5683509	4955648	727861	12.80654
Maharashtra	24560406	23304118	1256288	5.115095
Telangana	6536671	6084656	452015	6.915064
AP	11442705	11281072	161633	1.412542
Karnataka	10221324	9909095	312229	3.054683
TN	10285848	10283678	2170	0.021097
Pondicherry	95616	94704	912	0.953815
Kerala	9813032	9813032	0	0
Goa	128208	128208	0	0
Total	**213036453**	**188188691**	**24847762**	**11.66362**

Courtesy: REC, Saubhagya App, as on 10^{th} Oct 2017

Table 1.7: Status of un-electrified villages in India[9]

Selected State-wise Number of Un-electrified Villages Remaining in India (As on 08.03.2018)	
States	Un-electrified Villages*
Arunachal Pradesh	665
Chhattisgarh	92
Jammu and Kashmir	70
Madhya Pradesh	21
Manipur	2
Mizoram	2
Odisha	7
Uttarakhand	22
India	**881**

Courtesy: Note : * : Un-electrified Villages as on 28.02.2018 out of 18452 reported on 01.04.2015.

Source:LokSabha Unstarred Question No. 3419, dated on 15.03.2018.

1.3 CHALLENGES IN MONITORING OF REMOTELY LOCATED POWER GENERATION SYSTEMS

Livelihood of the remotely located people can be greatly enhanced by bringing then closer to the technological developments, and hence, we can also limit the migration from these villages to cities. Due to various reasons, technology has not been able to reach many villages especially, remotely located villages. One of the reasons is proper monitoring and maintenance of systems[15]. In many cases, it is observed that technological systems / projects are installed at many locations, but due to no proper monitoring and maintenance, the technical projects are under-performing and are of no use.The regular skilled maintenance is practically not possible as they are remotely located and physical access to the systems is challenging and time consuming, and hence, they remain unattended or rarely attended resulting in to either failure or dis-operation.

One of the main reasons for this is topological constraints. Many remote locations are still deprived of power either completely or partially. Setting up of plants in these locations is a difficult as well as risky task.

Though, some projects have been initiated, but their proper maintenance and monitoring could not be ensured due to unavailability of proper set up and trained workforce at such locations. Due to these various constraint and lack of infrastructure, the remotely located villages witness major setback and are behind the mainstream.

A great solution to these problems is designing and developing a system that could transmit all the required information related to the particular remotely located technical project. This brings in the role of wireless sensor networks which can be employed to monitor plants in remote locations even from a distance. Various technologies are available for wireless networking but deciding the best out of them is necessary[16]. There are pro's and con's to each technology in respect of power consumption, battery life, cost, range, hardware requirement, data transfer rate, efficiency, etc. So selection of the best combination of technologies available in accordance with the output required is of paramount importance.

1.4 REMOTELY LOCATED POWER GENERATION SYSTEMS IN INDIA

In India, initiatives have taken to meet the power demand of few of villages[6-8]. Mostly the power demand has been met through Solar power plants, Wind power plant and in some cases using small Hydro, Bio mass etc. However, over the period, most of the power plants are not performing up to mark. The present status of some of power plants has described in following sessions.

1.4.1 MICRO HYDRO POWER PLANTS

For the remotely located villages, reaching out of power lines is most complex and uneconomical in terms of initial investment. In view of this and to make power available to remotely located villages, it is advisable to generate power at the respective locations with available energy sources.

For this purpose, micro hydro power plants (MHP) can be one of the easiest and simple options. The remotely located villages are generally located at high terrain areas and there is a possibility of water streams in most of locations. Installing a 'runoff river' type power plant for power generation can be an easy and simple solution. The advantages of micro hydro projects are that they are pollution free, robust, low maintenance and cost effective[17].

The large scale hydro power plants are constructed with huge dams, reservoirs, pen stocks etc. The main parts of hydro power plant are dam, reservoir, pen stokes, turbines, generators, etc. Fig. 1.1, represents the elementary Hydro power plant[12].

As mentioned, the micro scale power plants are 'run off river' type plants, and hence,

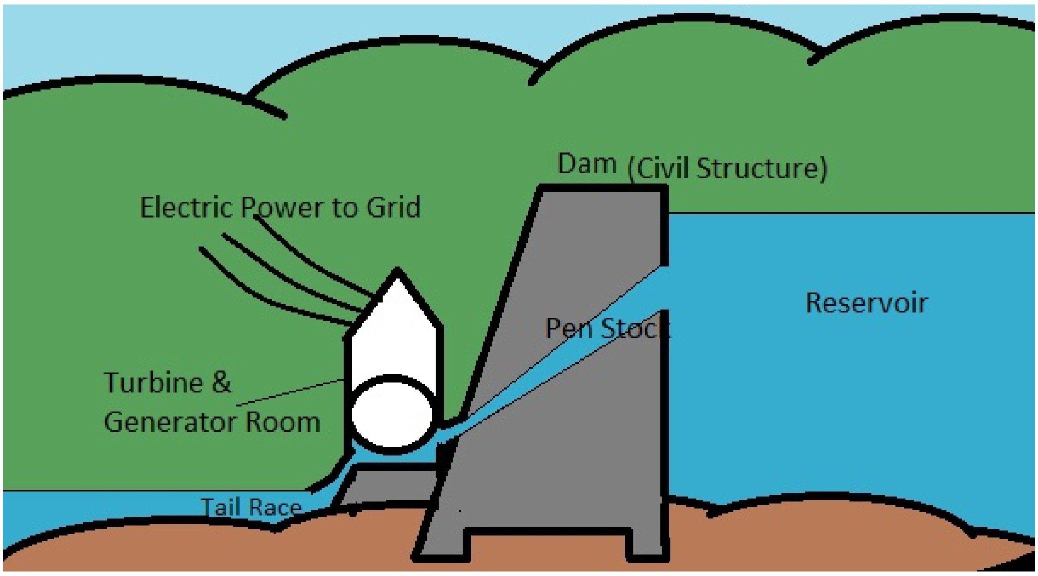

Figure 1.1: Hydro power plants

construction of dam, reservoirs, long penstocks, etc is not required. micro-hydro power plants can be called plug and play plant[18].

1.4.1.1 BENEFITS AND LIMITATIONS OF SMALL HYDRO POWER

BENEFITS:

Cost effectiveness: The micro hydro plants are generally run off river type plants and hence, dams, reservoirs, pen stocks etc., (high investment construction) is absent and thus the initial investment is low. Also as the plants run on naturally flowing water, the generation cost is very low.

Continuous operation: unlike Solar and wind, the flowing water is mostly available all the time and hence, the power generation is mostly uninterrupted. However, it is also true that, the rate of flowing water may see a seasonal change.

Few social and policy issues: In large scale Hydro power plants, hundreds of square kMs of land gets submerged and giant dams are to be constructed, there are many social, environmental and government policy issues. However, in case of micro hydro power plants, as power plants are run off type, there is hardly any damage to eco system and hence installation of micro hydro power plants is comparatively easy. There are not of much social litigation.

Efficient energy source: Micro hydro power plants, uses a stream of water and the maintenance is minimal. The effective cost of generation is very low.

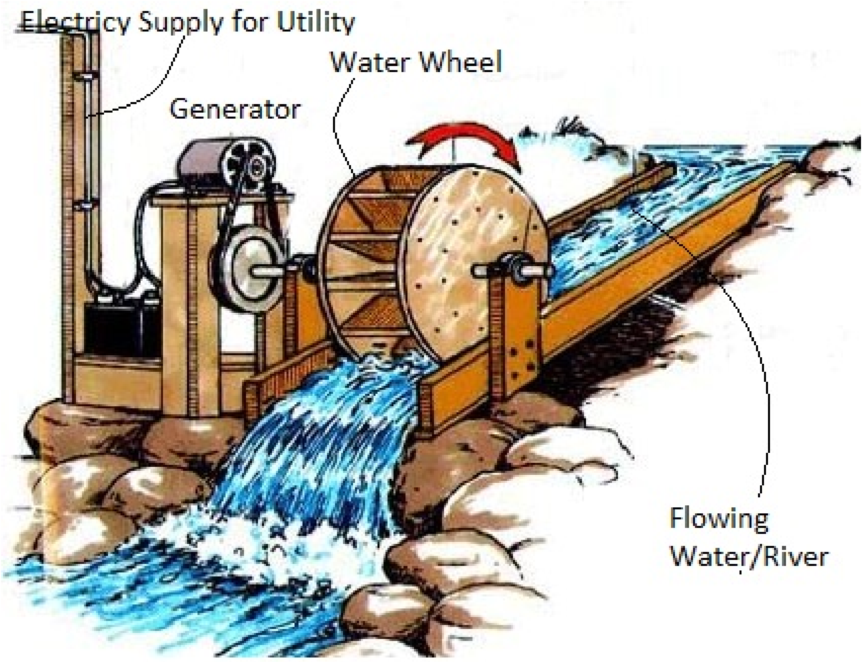

Figure 1.2: Small hydro power plant

Reliable electricity source: As the power is generated using stream of water, which is independent of Solar or wind, there is better reliability of power generation (Fig. 1.2).

No need of reservoir: Micro hydro power plants are run off type and they do not require reservoirs.

Grid integration: The power generated from these plants can also be integrated with locally available grid, if any.

LIMITATIONS:

Site characteristics: These plants can only be installed on the sites where continuous stream of water is available and hence, choice of location can be a challenge.

Future expansion: Generally, the streams are of smaller size and hence, increasing the capacity of existing plant is not possible. If energy expansion is required, an additional stream of water is required.

Seasonal effect: The power generation will vary as per seasonal change. During winter water freeze and in summer water will evaporate. In such cases the flow rate of water gets affected.

Environmental impact: Though the environment impact of micro hydro power plant is minimal, but it cannot be neglected. In certain cases, it may be required to divert the stream, rerouting, rerouting may be required. This results in tampering of eco system.

1.4.1.2 REMOTELY LOCATED MICRO HYDRO STATIONS IN INDIA

CASE 1: Location: Chakrata (Uttarakhand)

Key observations:

- Water carries lots of sediments and boulders
- Unavailability of screen at entrance.
- Open channel penstock.
- Growth of plants in open channel and Deposition of algae.

Causes:

- Turbine is damaged
- Damage penstock nozzle
- Loss of head due to deposition of algae and plants
- Flow speed is reduced because of spillage of water and friction

Recommendations:

- Maintenance should be done regularly
- Closed penstock should be used to increase the output and to avoid friction.
- Chemically treated blades should be used to avoid corrosion.
- Screen should be installed to avoid sediments and boulders.

CASE 2: Location: Tehri (Uttarakhand)

Key observations:

- Water flow speed is uncontrollable
- Water carries lots of sediments and boulders
- Unavailability of screen at entrance
- Lack of proper Maintenance.

Causes:

- Turbine is damaged
- Damage penstock nozzle.
- Cracks on blades

Recommendations:

- Valve should be installed to control the speed of water flow
- Screen should be installed to avoid sediments and boulders

CASE 3: Location:-Ukhimath (Uttarakhand)

Key observations:

- Water flow speed is uncontrollable
- Large size of blades(heavy turbine)
- Heavy weight of wooden turbine

Causes:

- Turbine is damaged
- Initial cost is increased
- Mismatch by fabricating large turbine for low potential head.
- Due to heavy weight of turbine speed is reduced (RPM), and hence reduced output/hour.

Recommendations:

- Retrofitting should be according to head.
- Small turbine should be installed so that the initial cost is reduced and speed is increased (RPM) according to potential head.

CASE 4: Location: Chakrata (Uttarakhand)

Key observations:

- i) Water carries lots of sediments and boulders
- Unavailability of screen at entrance.

- Open channel penstock.
- Growth of plants in open channel and deposition of algae.

Causes:

- Turbine is damaged
- Damaged penstock nozzle
- Loss of head due to deposition of algae and plants
- Flow speed is reduced because of spillage of water and friction

Recommendations:

- Maintenance should be done regularly
- Closed Penstock should be used to increase the output and to avoid friction.
- Chemically treated blades should be used to avoid corrosion.
- Screen should be installed to avoid sediments and boulders.

1.4.1.3 KEY PARAMETERS OF INTEREST FOR REMOTE MONITORING OF MICRO HYDRO STATIONS:

1) Discharge at Turbine Nozzle:

The rate flow of water is a most important parameter that needs to be monitored to ensure and estimate the proper performance of the power plant. The electrical power generated is directly related with rate flow of water. It is measured in cubic meter per second. This parameter will also help in future estimation based on past performance. By comparing the data one can also estimate about the status of water flow lines.

2) Flow rate at inlet of pen stocks / water channel:

The rate flow of water is a most important parameter need to be monitored to ensure and estimate the proper performance of the power plant. The water is carried through pipes called as pen stocks or channel from reservoir to the turbine room. Ideally the rate flow of water from at the inlet should be same as the rate flow of water at turbine end. But due to leakage and various other reasons there will be loss of water and pressure from inlet to outlet.

This loss of water can result in to under performance of power plant and leakage will cause in to reduced power generation (units generation) availability The leakage within the pain stocks or channel can be calculated by comparing the rate flow of water at inlet and the rate flow of water at outlet (turbine end). Thus it is important to monitor the flow rate of water at inlet of the pen stocks / water channel.

3) Reservoir (if any) Water Level:

The storage type hydro power plants store the water in reservoir. This stored water will be used for the purpose of power generation. In such power plants the water level will be again a useful parameter for electrical power generation estimation. The water level shall provide the working head. The power output from a hydro power plant is directly proportional to working head (available head).

The status of water level will also provide the availability of water in reservoir and accordingly it will help in estimation of power generation and future planning.

By knowing the water level, the control room can take decision about the release of water flow for various purpose including irrigation and power generation.

4) Turbine Speed and Frequency of EMF Generated:

The turbines are coupled to alternators. These alternators convert mechanical energy in to electrical energy. The frequency of EMF (electromagnetic field) induced is given by speed of rotation of alternator. To ensure the frequency of alternator to be same as grid frequency, the alternator (and turbines should rotate at the desired speed). Any variation from the desired speed will cause alternators to lose synchronism. It is essential to monitor and control the speed of rotation to maintain synchronism.

5) EMF Generated / Voltage Level:

The alternators are to be synchronized to grids and will be sharing the appropriate level of load. The real and reactive share of load is governed by frequency and voltage level. To maintain the required synchronism with the grid the frequency and voltage level of alternator need to monitored in real time basis.

6) Current:

The alternators are designed for specific electric power output. Any increase in power sharing may result in to excessive losses and overheating of alter and subsequently cause in to breakdown. It is important to ensure the current rating / loading of alternator is within specified limit. To ensure the level of current is within limit, it is important to monitor the current with the help of current transformers.

7) Power Factor:

For alternating current applications mere, monitoring the voltage and current is not enough. It is equally important to monitor the phasor relationship between them. The angular displacement between voltage and current is called as phasor angle and cosine of this angle is described as power factor. The monitoring of power factor will provide the information of active and reactive power shared / supplied by alternator. For the purpose of synchronization it is not only important that to focus on active power loading but it is also important to control on reactive power loading. The true and real time monitoring of power factor will indicate the operating health status of the alternator.

8) Temperature Rise:

The electrical equipment is prone to losses and these losses are converted in to heat, which then results in rise of temperature of the equipment. This equipment needs to be cooled with the help of external cooling, so as to avoid any temperature rise above specified temperature. The temperature rise of equipment is very harmful for electrical equipment, as the insulating materials used in equipment are sensitive to temperature rise above specific temperature. This allowable temperature rise depends for a specific insulating material depends on the class of that insulating material. The insulating materials are classified in various class from ‘Class Y‘ (Max temperature of 95°C) to ‘Class C‘ (Max temperature of 200°C), as per Table 1.8.

Table 1.8: Class of insulation

Class of insulation	allowable temperature in °C
Y	95
A	110
E	120
B	130
F	155
H	180
C	200

As the temperature start rises above the specified temperature, the life of insulating material deteriorates and it has adverse effect on the performance of electrical equipment. Thus, it is important to know the temperature rise of electrical equipment like Generators, Transformer, CTs, PTs, Control panel etc.

With technological upgradation, most of the control and sensor devices are semiconducting in nature.

1.4.2 MICRO SOLAR POWER PLANTS

Solar Energy can be converted in to Electrical Energy with the help of PV cells. When the sunlight falls on PV cells, made of special semiconducting material, the kinetic energy of photos will cause separation of positive ions and electrons from the semiconducting material and thus the light energy is converted in to electrical Energy. [13] PV Cells then connected in series and parallel to obtain the required voltage and current level. These series/parallel connected PV cells are tightly stacked under highly reflective glass module to protect is from rain, wind and dust. These cells tightly stacked under and formed a casing are called as PV modules. These PV modules are available in various Voltage and watts ranges, as shown in Figs. 1.3 - 1.6.

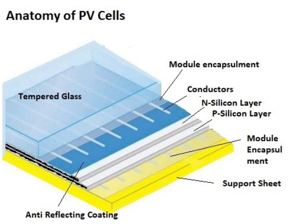

Figure 1.3: Anatomy of PV cells[13]

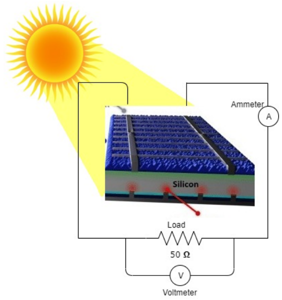

Figure 1.4: Typical fabrication of solar Panel[13]

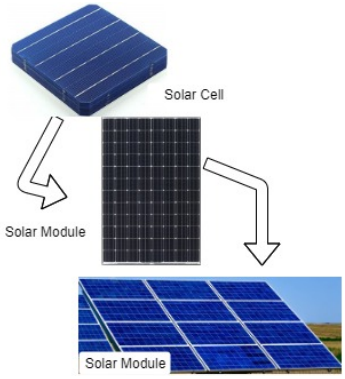

Figure 1.5: Anatomy of PV cells[13]

Figure 1.6: Working of PV cells[13]

The PV modules are placed on mechanical structure such that maximum area of module is exposed to sunlight thought the day.

These PV models installed on structure are ready to use for the purpose of power generation. For example, say one of the panel is designed for 12 V, and 168 Wp, then this model will be generating peak power of 168 W at a voltage of 12 V [19,20].

Like PV modules, solar modules also can be connected in series and parallel to get the required voltage and power rating. Depending on the number of panels, the rating of plant

Figure 1.7: A typical arrangement of solar power plant[13]

can be calculated (Fig. 1.7). The voltage and power rating of solar power plants can be in the range of kV and MW. These power plants can be standalone type or can grid connected type.

The standalone type plants are generally in smaller power rating and hence generally classified as ‘Micro Solar Power Plants‘. The standalone type of plants generally supply power to a limited group of consumers. The standalone micro solar power are generally remotely located and sometime can be part of Micro-grid.

Grid interactive power plants are connected to grid. As the standard electrical grid is AC and the power generated by PV cells is DC, for grid interactive power plants used inverter to convert DC in to AC and then with the help of transformer they are connected to grid.

Solar Power plants (Fig. 1.8) can be very small size, that is in few watts up to MW size. Weather Power plants is in micro watt size or MW size, the basic philosophy remain same and operational and practicality also remains same.

As the solar power plant convert solar energy in to electrical energy, it is needless to say, these plants can generate power only during dawn to dusk.

The performance of solar panel depends of various factors as Solar Insulation, Dust

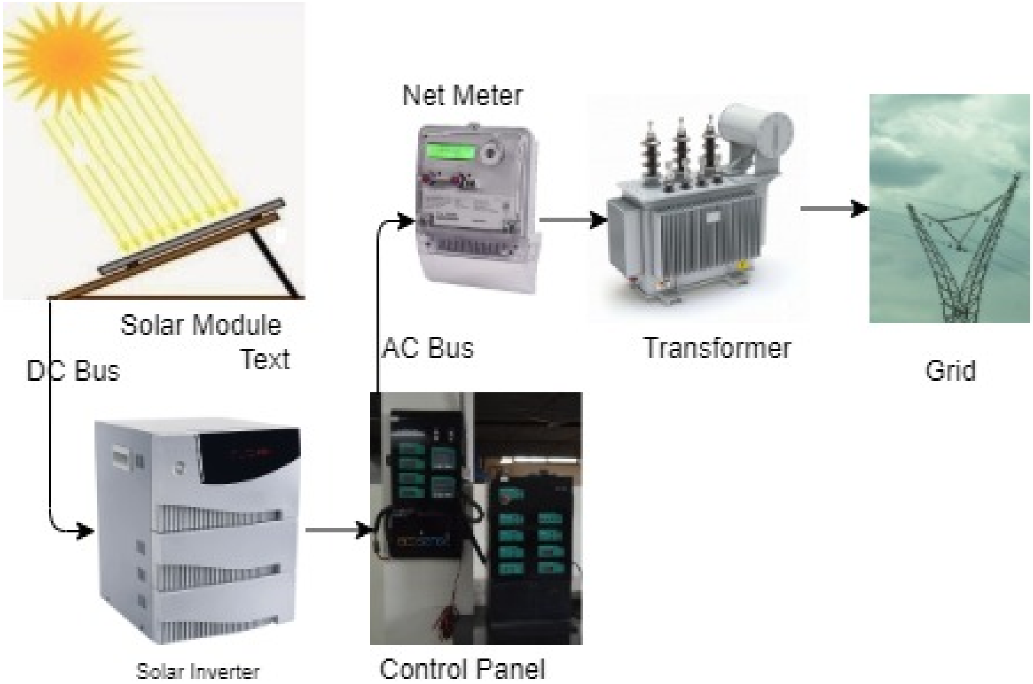

Figure 1.8: A typical grid interactive solar power plant[13]

deposited on module (panel) glass, Temperature of module, angle of inclination etc[21].

1.4.2.1 BENEFITS AND LIMITATIONS OF MICRO SOLAR PLANTS BENEFITS:

BENEFITS:

Construction and Operation: As already described above, for solar power plants as only panel(s) are to be installed on simple structure and there are no moving parts, the construction is very simple. However, it requires much larger area per MW compared to any other plant.

Low Maintenance and Noiseless Operation: Since Solar Power Plants, have no moving parts and hence it requires hardly any maintenance and there are no components making noise.

Least Possibility of breakdown: As there are no moving parts, there is hardly any wear and tear and chances of fault occurrence is minimal. If at all any fault occurs, they are electrical faults and hence, the chances of breakdown are minimum.

Quick and Immediate Installation: Construction of Power plants means only installation of structure, laying modules and making connections. Few MW size power plants can be installed 2/3 months' time.

LIMITATIONS:

Availability of Power: As the name indicate, Solar Energy is converted in to Electrical Energy and hence power generation is available only during sunshine hours' time. The Power plants remain ideal during off Sunshine period.

Dust or Dew Deposition will Affect the Performance: Dust or dew will reduce the reflectivity of glass and hence less sunlight shall reach at solar cells that will reduce the power generation and hence affect the power plant performance. The efficiency of Solar Cells is very low (at present in the range of 16-17%); minor dust deposition will affect the performance severely.

Large Space Requirement: Presently commercial standard is around 5 acres for 1 MW. With growing land rates, it's really challenging to get the land for very large MW power plants.

1.4.2.2 REMOTELY LOCATED MICRO SOLAR PLANTS IN INDIA:

CASE-1

Location: Auroville (Puducherry)
Year of Installation: 1997
Module Type: Mono crystalline Silicon
Actual Power Rating: 75Wp
Period (Age): 16 years

Module Component	Status of Degradation	Type of Degradation
Encapsulate	Yes	Dark discoloration, No Delamination
Back sheet	No	Like New
Metallization	Yes	Dark Corrosion
Junction Box	No	Good Seal
Frame	No	Like New

Key observations:

(i) Discoloration on modules i.e. yellow discoloration

(ii) Cracks in the solar cell

(iii) Corrosion in the terminals

(iv) Chalking (white powder) of back sheet

(v) Corrosion in the cell and string interconnects

Causes:

(i) Improper cleaning of module

(ii) Less maintenance

(iii) If Temperature increases silicon cell (thin film) become brittle and breaks

(iv) Improper insulation of panel (encapsulate)

Recommendations:

Module which is not performing well should be removed, as it limits the performance of system because module strings are connected in series. Junction box should be sealed properly to avoid water entry due to which terminals are corroded and lead loss in power output, Modules should be cleaned at regular interval.

CASE- 2

Location: Sagar Island (West Bengal)
Date of Installation: 1998
Module type: Mono Crystalline Silicon
Power Rating: 75Wp
Period (Age): 15 years
Description of Module:

Module structure	Status of degradation	Type of degradation
Encapsulate	Yes	Dark discoloration
Back sheet	No	Like new
Metallization	Yes	Light corrosion
Junction Box	No	Good seal
Frame	No	Like new

Key observations:

(i) Dark discoloration in the center of each cell.

(ii) Minor corrosion in the cell interconnects

(iii) Chalking from the back sheet of the module

Causes:

(i) Improper cleaning of module

(ii) Less maintenance

(iii) If temperature increases, silicon cell(thin film) become brittle and breaks

(iv) Improper insulation of panel (encapsulate)

Recommendations:

Prevent any scratches or puncture in the modules. Junction box should be sealed properly to avoid water entry due to which terminals are corroded and lead loss in power output, Modules should be cleaned at least once a week.

CASE-3

Location: Tilonia (Rajasthan)
Year of Installation: 2000
Module type: Mono Crystalline Silicon
Power Rating: 45Wp
Period (Age): 13 years
Description of Module:

Module Structure	Status of Degradation	Type of Degradation
Encapsulate	Yes	Discoloration, Delamination of cells
Back sheet	NA	Like New
Metallization	Yes	Dark Corrosion
Junction Box	Yes	Loose/Brittle
Frame	No	Like New

Key observations:

(i) Discoloration and delamination in cell

(ii) Discoloration in the Metallization (fingers)

(iii) Tilt angle of module is 160 whereas latitude is 260 (Non-optimum tilt).

(iv) Heavily soiled

(v) Front glass broken

Causes:

(i) Improper cleaning of module

(ii) Less maintenance

(iii) If temperature increases silicon cell (thin film) become brittle and breaks

(iv) Improper insulation of panel (encapsulate)

Recommendations:

Prevent any scratches or puncture in the modules. Junction box should be sealed properly to avoid water entry due to which terminals are corroded and lead loss in power output, Modules should be cleaned at least once a week. For higher energy generation tilt angle should be set at correct angle.

CASE-4

Location: Hanle (J&K)
Year of Installation: 1998
Module type: Mono Crystalline Silicon
Power Rating: 75Wp
Period (Age): 15 years
Description of Module:

Module structure	Status of degradation	Type of degradation
Encapsulate	Yes	Dark discoloration, Delamination
Back sheet	No	Like new
Metallization	Yes	Light corrosion
Junction Box	No	Good seal
Frame	No	Like new

Key observations:

(i) Discoloration and delamination in cell

(ii) Discoloration in the Metallization (fingers)

(iii) Tilt angle of Module is equal to the latitude of the place

(iv) Cracks in solar cell

Causes:

(i) Improper cleaning of module

(ii) Less maintenance

(iii) If Temperature increases silicon cell(thin film) become brittle and breaks

(iv) Improper insulation of panel (encapsulate)

Recommendations:

Prevent any scratches or puncture in the modules. Junction box should be sealed properly to avoid water entry due to which terminals are corroded and lead loss in power output,

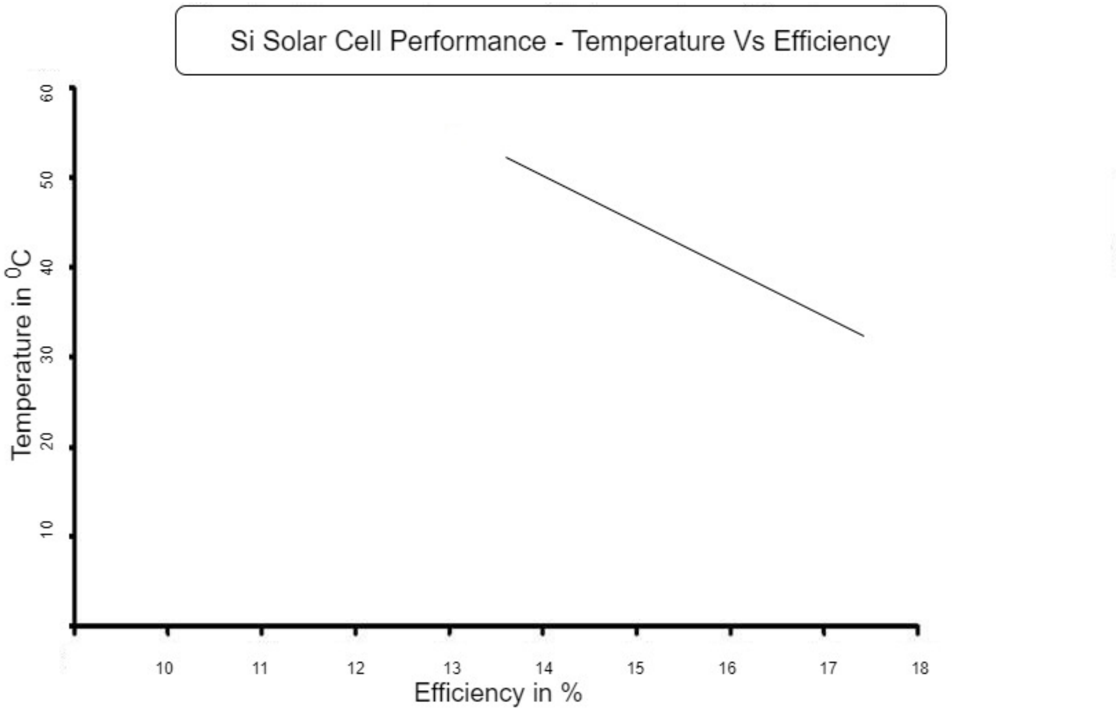

Figure 1.9: Temperature vs efficiency characteristics of solar panel[13]

Modules should be cleaned at least once a week. The cables should be checked regularly for any breakage.

1.4.2.3 KEY PARAMETERS OF INTEREST FOR REMOTE MONITORING OF MICRO SOLAR PLANTS

1. **EMF, Current and Power Factor:**

   As described earlier, these are the most critical parameters to estimate the performance of power plant. The real time monitoring of these parameters is one of essential requirement.

2. **Temperature of Solar Panels:**

   The efficiency of Solar panels decreases as the temperature of panel increases. The typical relation between Solar Panel efficiency and temperature rise is as shown in Fig. 1.9.

3. **Dust Deposition:**

   Due to dust deposition on solar panels, the refraction level of glass changes and that causes in to lower amount of solar rays penetration on PV cells, in turn it results in to reduced power generation.

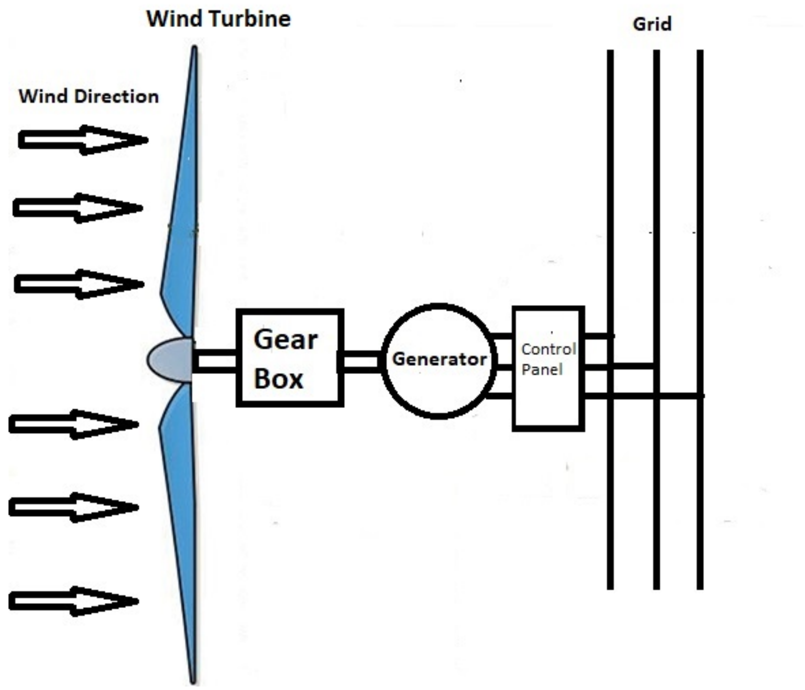

Figure 1.10: A typical structure of wind turbine[14]

1.4.3 SMALL-SCALE WIND POWER PLANTS

Wind power plants converts wind energy in to electrical energy. As simple as when fan rotates, the blades of the fan cause wind to blow in the same way; if wind flows; it will rotate the blades of the fan (Fig. 1.10).

As per the Faraday's law of Energy Conversion, the energy conversion depends on the rate of change of flux cut, in wind generators it is also true that, as the wind speed changes, the rate of flux cut changes and in turn the EMF generated and power generated keep changing.

However, changing power output may not be a crucial as the change in EMF level and change of frequency (Frequency of EMF generated is directly proportional to speed). Thus to maintain EMF and frequency in synchronization with grid, very specific arrangements are to be made in windmills.

The entire assembly of blades is called as rotor. There are various types of rotors as vertical axis rotor or horizontal axis rotor. Rotors generally have two blades or three blades. This rotor (two or three blade) is called as wind turbine[14].

Among two blades and three blades turbine, three blade turbines are having better performance output and hence are more popular. The performance of wind turbines mostly

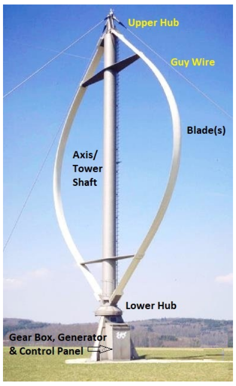

Figure 1.11: Vertical axis turbine[14]

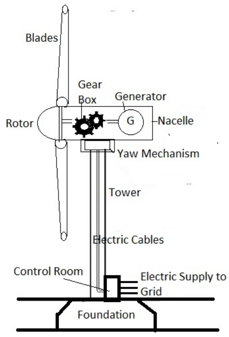

Figure 1.12: Horizontal axis turbine [14]

Figure 1.13: Two blade turbine[14]

Figure 1.14: Three blade turbine[14]

depends on the design and shape of blades. To get the best performance from a wind power plant, the blades should be perfectly designed and selected. Thus, in wind turbines, blades are most crucial, delicate part and costliest part of entire assembly. As the blades are most delicate, they are also most prone to maximum damage.

Wind turbine is connected to a specially designed gear system. A gear system is specially and critically designed for a wind turbine so as to maintain desired speed at the generator rotor. This entire arrangement (Gear box and generator) is kept in nacelle. This nacelle is kept on the top of tower, called as Wind tower.

Wind towers have sufficient height so that the entire turbine is free to rotate (perpendicular to ground). The nacelle is also free to rotate on the top of tower over 360°. This direction Nacelle is guided by a glider so face to wind direction. As nacelle rotates (parallel to ground), the direction of blades also changes, this ensure that the wind turbine blades always faces the wind direction (Figs. 1.11 - 1.14).

As wind turbine always faces wind direction, it always rotates at the maximum speed of wind. The output of a wind turbine varies directly to the third power rotor speed of wind turbine.

A single Wind turbine can be small in size and up to few MWs. As the wind turbines have some critical design and construction phase, generally small size wind turbines are costly and economically not very viable. However, there some advantages over solar power plants makes them popular over solar power plants.

1.4.3.1 BENEFITS AND LIMITATIONS OF SMALL WIND POWER PLANT

BENEFITS:

Power Available at any Time of the day:
Unlike Solar power plants, which can generate during only sun shine hours, Wind Power Plants can generate electricity, subject to availability of wind, at any time of day.

Clean and Pollution Free Power Generation:
As the primary source is flowing wind and no other energy source is used, the power generation process is neat and clean.

Low Cost of Generation:
As the primary source is flowing wind which is naturally available, there is no fuel cost. However, the wind mills require high maintenance cost. Over all the cost of generation is low.

LIMITATIONS:

Delicate and Complicated in Construction:
As the wind power plants have delicate parts as blades, gear boxes etc., the construction and transportation is difficult/crucial and operation is complex compared to Solar Power Plants.

Create Noise and Require More Maintenance:
Wind turbines creates noise during operation and due to delicate and rotating parts like blades, gears etc. it required more maintenance.

1.4.3.2 REMOTELY LOCATED SMALL - SCALE WIND POWER PLANTS IN INDIA

CASE 1

Location: Chhindwara (Madhya Pradesh)
Name of Plant: Dend
Date of Closing: 11 February 2016

Key Observations:

(i) Maintenance below minimum acceptable level.

(ii) The wind power penetration has resulted in to increased real and reactive power, in turn resulted in undesirable operation.

(iii) The existing transmission corridor is below requisite capacity to transmit the power generated by wind mills. To meet the increased power demand additional or enhanced capacity of transmission line is required.

(iv) Improper wind speed regulation.

Causes:

(i) Wind Power Plants are very delicate in operation and prone more maintenance. Also at it is very delicate and complicated in operation, it required skilled and properly trained labour. Thus, the labour cost for maintenance of plant more. If the performance of plant is not up to mark, in that case labour cost can be much higher than the power generation.

(ii) As the performance was not adequate and labour cost is much higher, the RoI was not up to mark and economically it was difficult to operate.

Recommendations:

(i) Maintenance should be done regularly so that noise and aesthetic pollution is reduced.

(ii) It is recommended to compensate reactive power at the wind farm substation level. Along with dynamic compensation at the 11/230 kV substation will also help in improving performance.

(iii) An additional dedicated transmission corridor may be added to the existing network, to ensure the full utilization of wind power generated.

(iv) The existing dynamic compensation plant can be re-optimized and relocated to get better performance.

CASE 2

Location: Chittorgarh (Rajasthan)

Name of Plant: Bassi

Date of Closing: 04 February 2016

Key Observations:

(i) Relatively Less maintenance.

(ii) As the wind turbine generator installation increases, the short circuit analysis used to identify weak points can result in power evacuation problem.

(iii) Low Voltage Ride Through (LVRT) capability reveals that unstable operation and low voltage problems. The same has been analyzed through stability analysis as well.

(iv) As the wind power generation increased, the real and reactive power losses also increased and causes in poor system performance.

Causes:

(i) Wind power plants are very delicate in operation and prone more maintenance. Also at it is very delicate and complicated in operation, it required skilled and properly trained labour. Thus the labour cost for maintenance of plant more. If the performance of plant is not up to mark, in that case labour cost can be much higher than the power generation.

(ii) As the performance was not adequate and labour cost is much higher, the RoI was not up to mark and economically it was difficult to operate.

Recommendations:

(i) Maintenance should be done regularly so that noise and aesthetic pollution is reduced.

(ii) The generators performance should be enhanced using LVRT capability.

(iii) Reactive compensation is required at the wind farm substation.

CASE 3

Location: Bidar (Karnataka)

Name of Plant: Nirana

Date of Closing: 18 February 2016

Key Observations:

(i) As long the wind generators are performing below half of the rated capacity, the transmission lines are able to carry the power. However, if the wind generators perform above even half of rated capacity, transmission lines get over loaded.

(ii) Relatively poor maintenance.

(iii) As the wind turbine generator installation increases, the short circuit analysis used to identify weak points can result in power evacuation problem.

(iv) Low Voltage Ride Through (LVRT) capability reveals that unstable operation and low voltage problems. The same has been analyzed through stability analysis as well.

Causes:

(i) Wind power plants are critical in operation and prone increased maintenance. Also they are very delicate and complicated in operation, and hence skilled and properly trained technicians are required. It increases the maintenance cost of power plant. The increased labour cost is not subsidized by the improved performance of plant.

(ii) Due to poor performance and higher labour cost, the RoI was not up to mark and economically it become difficult to operate.

Recommendations:

(i) Proper and regular maintenance to reduce maintenance and noise.

(ii) A suitable transmission corridor can be established.

(iii) The wind generators can be provided with LVRT capability.

1.4.3.3 KEY PARAMETERS OF INTEREST FOR REMOTE MONITORING OF SMALL-SCALE WIND POWER PLANTS

1. **EMF, Current and Power Factor:** As described earlier, these are the most critical parameters to estimate the performance of power plant. The real time monitoring of these parameters is one of the essential requirement.

2. **Temperature Rise:** As discussed above, the electrical equipment should be allowed to operate in specified temperature range only, based on the class of insulation. Any excess in the operating temperature, above specified temperature, may result in reduced life of insulation and life of equipment in turn.

3. **Turbine Speed:** The performance/output of wind turbine varies directly proportional to third power of rotor speed. Primarily it is required compare the output power to the wind speed. It is also necessary to measure the speed of wind, as over speed/turbulence may damage the blades/system. It is required to lock the rotor during turbulence.

1.5 REAL-TIME DATA MONITORING SYSTEMS

In previous section, it is described that, the some efforts has been made to provide electricity to the remotely located villages. Many villages have been provided with independent standalone power plants to fulfill the electricity need of villages. However, it is also observed that, many of these remotely located power plants are not in operation or under performing over a period. The key reason behind the under performance is lack of maintenance and monitoring of power plants.

There are various reasons for poor maintenance of these remotely located power plant as discussed in previous sections. The major reason for lack of 'skilled attention' for these power plant is difficulty in accessibility to these power plants, due to their geographical location. However, these power plants can be given proper attention well in time to avoid any major breakdown, if there is any mechanism to monitor the operation parameters of these power plants.

In this research work, a methodology has been suggested in which these operational parameters would be transferred on real time basis to a suitable location using advanced communication technology.

Each system has its own typical parameters to be measured and monitored to understand the performance. The parameters can be measured using various instruments. The various types are instruments can be used for same. With continuous improvement in technology, various sophisticated instruments are available, which can not only monitor the data but also can store and communicate the data. These instruments indicate the data on real time basis.

Real Time Data Monitoring (RTDM) is a set of procedure in which the user or an administrator would be able to complete monitor and control the whole system under consideration. In this the operation is expanded such that he can review, evaluate and even modify the any process in the form of addition, deletion, and modification. The input of all these process is any use of data on software, a database or a system as a whole. The system is designed in such a manner that the user or administrator would be able to assess the data of whole processes along with all of its function in real time (Fig. 1.15).

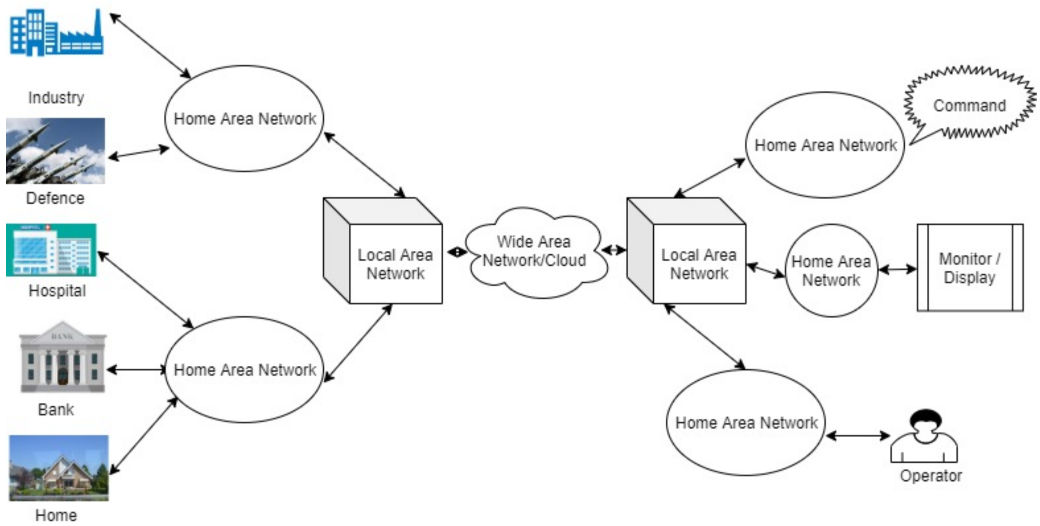

Figure 1.15: Real-time data monitoring (Conceptual)[22,23]

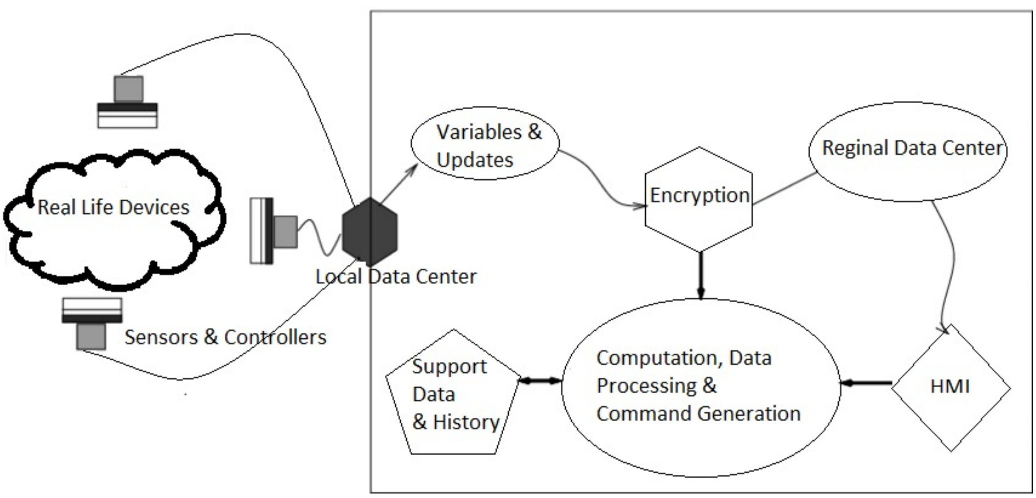

Figure 1.16: Real-time data monitoring (Application)[22,23]

The primary role of real time data monitoring is not only monitoring the system but also managing the system in the application, use and consumption of data across a complex Information enabled system or on a standalone system (Fig. 1.16). The system may the stand alone or combination of software and database [22-24]. Typically, Real time data monitoring software/system make available through data administrators. The work of the data administrator is to have visual insights into the data. The data can be fetched from various sources, these includes web server, network and database. It will also inform the instant notifications for any specific events, where the data flow is going out of specified range.

Most existing embedded applications demand more complex and sophisticated debugging tools, providing methods to reduce the development cycle, and therefore, the time-to-market. The DMCI (Data Monitoring and Control Interface) is responsible for providing dynamic input control of application variables. Application-generated data, with the help of dynamically assignable graph windows, can be accessed using this.

Motor control and power conversion are the typical applications that demands high-speed data monitoring from this interface [23]. The task is achieved with the existing on-chip debugging tools and the use of a communication link in between host PC and a target device. RTDM and DMCI form an alternative link in between PC and target device, which is used for the debugging applications. These tools helps in getting the in and out flow of data through the target device. Developers will be benefited to run their applications using this.

A Real Time System (RTS) is a time based system where the outputs produced are sig-

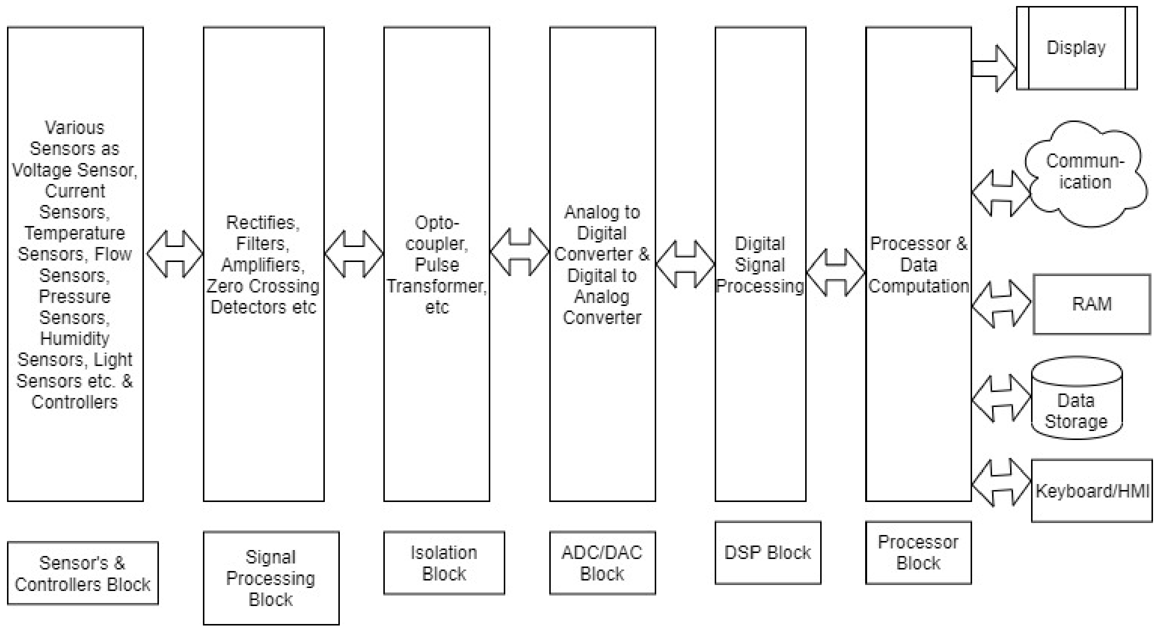

Figure 1.17: Real time data processing[22,23]

nificant in time. The outputs should be generated within a well-defined time line or deadlines. The correct function of the system not only a function of logical results produced, but also on the response time of the produce results. The system provides an incorrect state if a correct result is produced either early or late with regard to the specified time line. A simple block diagram representation of the system is shown Fig. 1.17. The inputs sources may of any among sensors, switches, and communication links. Similarly the output may be from motors, alarms, switches, communication links and displays. The output of the system is associated with specified time bounds.

Real-time systems are classified in two broader groups. These are:

Hard RTSs: In this sort of systems, it is totally imperative that a response has to occur within the specified time line. Typical examples of these time lien based systems are air traffic control, on board air craft control, process control in industries.

Soft RTSs: The systems where response times are important but not exclusively dependent on deadline comes under this category. Here the system does not cease to stop functionally even if deadlines are missed occasionally. Typical examples are time out protocol based communication systems. If the receiver acknowledgment is not received before the deadline, a time out arises for the message to be resent again. The missing the deadlines can be tolerated occasionally; else resent message would create a jam in the traffic.

1.5.1 BENEFITS AND CHALLENGES IN REAL-TIME DATA MONITORING

Real-time data monitoring systems possesses a few advantages over the planned maintenance as

1. It is responsible in improving the reliability of system.
2. It is accountable for the reduction of the cost of maintenance.
3. It is responsible for a decreased in the number of maintenance operations.
4. It causes a reduce influences of human error.

However, the system has certain challenges as:

1. It has high installation costs. Therefore, the cost of the equipment is more for less number of users and minor equipment items.
2. It possesses an unpredictable periods of maintenance, hence the periodical cause costs are divided unequally.
3. It established an increase in the number of parts, which need to be maintenance and check regularly.

1.6 WIRELESS TECHNOLOGIES FOR REAL TIME DATA MONITORING

The remotely located system are ‘remote‘ in many perspectives as accessibility, feasibility, geographically etc. Due to these constraint it is practically not possible to monitor the data on real time basis at the physical site, hence it is required to communicate the real time parameters from remotely available locations to the easily accessible location. For the purpose of communication, many data communication technologies are available including wired and wireless. There are many geographical constraint to lay the cable for wired communication. It is proposed to consider wireless technologies for the purpose of data communication. There are various wireless technologies are available for the purpose of data communication.

Table 1.9: Mobile subscription outlook

Subscriptions	2014	2020
Mobile Phone	7.1 million	9.2 million
Mobile Broadband	2.9 million	7.7 million
Smartphone	2.6 million	6.1 million
Tabs, routers	250 million	400 million

1.6.1 COMPARISON OF WIRELESS TECHNOLOGIES [25-27]

In the recent years, the world has seen a dramatic and stupendous increase in the use of mobile communication devices for various function and connections. The devices are basically broadband, multi-functional and high speed smartphones, with some share of tablet devices. Mobile users have been handling more data than the usage of voice with these mobile devices. The number of different wireless mobile devices as their subscription base in between 2014 and 2020 is tabulated.

The above mentioned Table1.9 represents an enormous and rapid growth of the mobile subscription base. The subscription base includes the mobile devices phenomenal growth also. The growth in mobile devices (such as tablets, mobile personal computer, and routers) is on a slower side than the growth of smartphones and mobile broadband devices. The current smartphones not only acts an integrated source of all mobile devices but it has much more functional capability also.

New connectivity technologies have been emerged to withstand the demand and afore stated growth. The sustainability of the communication market is very much related to all these. Some of the key technologies for an over whelming cultivation of these comprise of Wireless LAN (WLAN), Wireless Fidelity (WiFi) 3-G (EDGE), 4-G LTE, Wi-Max, etc. These technologies are monitored by various wireless data communication protocols and standards. These standards provide a framework on how the systems are built, integrated and communicated with each other in the network.

The recent mobile devices, which are solely on the broadband standards, exploit the wireless fidelity connection. The smartphones floating into the markets are functionally on the third generation to fourth generation wireless mobile communication technologies.

A comparison between different short-range wireless technologies is presented in the Table 1.10. It is preceded by a Fig. 1.18 showing the graphical comparison. The below mentioned Fig.1.18 and Table 1.10 give a good representation of a smooth comparison between wireless technologies that are used extensively now a days. The presentation of the comparison is conceptual in nature without any detail technological point of observation.

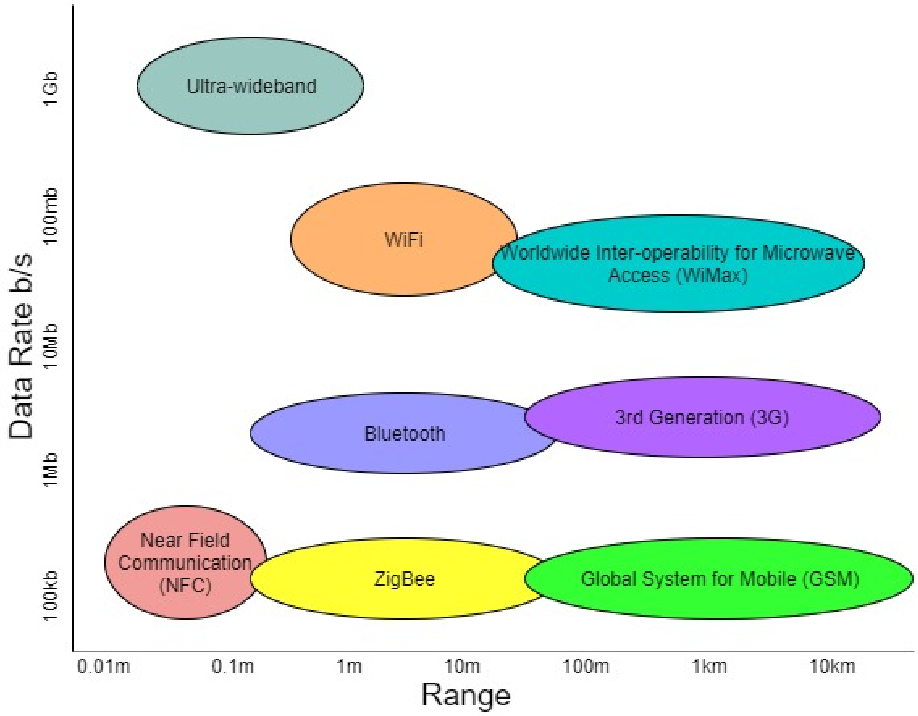

Figure 1.18: Comparative representation of wireless technologies[26]

On the other hand, this may be freely used as a quick tool on the choice of making decision. The choice is the application and implementation of technology under individual choice of specific application. The comparison mainly comprises of the data such as operating range, rate of data transmission, possibility of structuring the network building.

Table 1.10: Comparison of Short range wireless technologies[26]

	ZigBee	Wi Fi	Bluetooth	Wireless USB
Data Rate	20, 40 and 250 kbps	11 and 54 Mbps	1 Mbps	62.5 kbps
Range	10-100 m	50-100 m	10 m	10 m
Operating Frequency	2.4 GHz	2.4 and 5 GHz	2.4 GHz	2.4 GHz
Topology	Star or Mesh	Point to Hub	Point to Point	Point to Point
Device and Application complexity	Low	High	High	Low
Power consumption	Very low	High	Medium	Low
Typical Application	Sensor network, Home control automation	Wireless LAN connectivity, Broadband Internet Access	Wireless Connectivity	PC peripheral connections

GSM - the second generation mobile communication technology- has been excluded here, because has been developed into a highly mature and it has a very large range of operation.

Any of the suitable technology can be used for the purpose of real time data monitoring of remotely located power plants.

1.7 CONSTRAINTS WITH WIRELESS TECHNOLOGIES IN REMOTE LOCATION MONITORING

1.7.1 NEED OF OPTIMIZATION

As discussed in various sections above it is studies that, with the help of various technologies, the livelihood of remotely located villages can be improved. With the help of renewable energy, electrical energy can be generated at these locations. The electrical energy can improve livelihood and also make the local habitat more empowered. The electrical energy can create entrepreneurial and job opportunities. It will also help in reducing migration. But as observed, to ensure the continuous operation the maintenance and condition monitoring of these systems is also important.

As discussed, for regular maintenance it is important to study the operating parameters regularly. And with remotely located system, it is difficult to monitor the parameters on real time basis. But with the help of wireless communication technology it is possible to communicate data from one location to the expected location. Thus, the wireless communication technology can act as lifeline for remotely located system.

It is also seen that, there are various communication technologies available and each technology has their own challenges. One of the critical constrain is 'communicable distance'. As certain technologies can communicate over thousands of kilometers, where as some other technologies can communicate over few feet. The technologies that can communicate over thousands of kilometers will require some critical infrastructure and that may not be available at the remote locations, but with the help of other technologies, localized network can be developed and data can be communicated over small distances.

In the research work, it is proposed to integrate various communication technologies to meet the requirement. It is proposed to create wireless localized are network (WLAN) at remote location using short range communication technology, which can be developed easily and with minimum investment. This localized network may be integrated with same

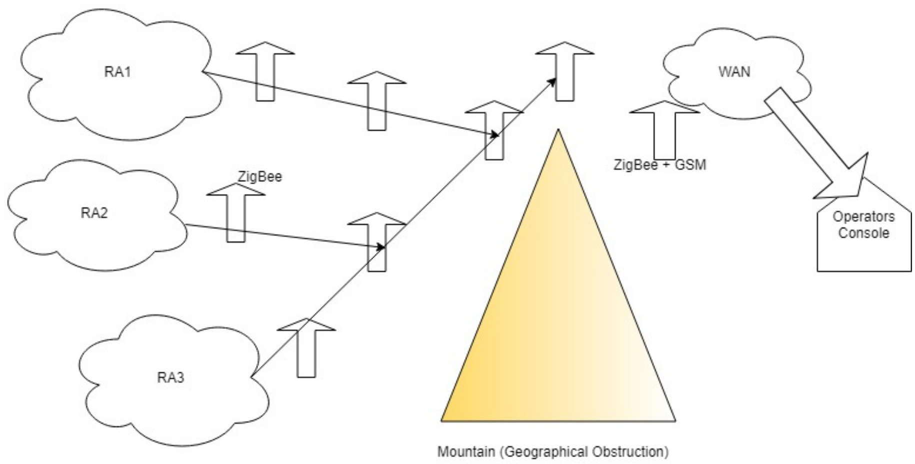

Figure 1.19: Indicative diagram for data communication

or other technologies and with multiple nodes (a chain of nodes) and data will be communicated till the location where long distance communication network (say GSM, OFC etc) is available so that the data can be easily communicated from the remote location to the desired (centralized) location. The indicative diagram is as in Fig. 1.19.

It can be seen that, as the local distance (Distance from remote location until the long distance communication network is available) increased, the number of communication nodes increases. There are certain issued associated with increased nodes as

(i) the probability of data loss (packet loss) increases

(ii) increased possibility of noise

(iii) the power consumption at each node increases

(iv) maintenance increases

(v) increased cost as each nodes results in to additional investment

(vi) Overall system reliability decreases.

Thus, in the research work it is proposed to minimize the number of nodes required for WLAN until the long distance communication is available. As the remote locations are at distinct location, the communication between these two points within WLAN is very complex and involve various constraint. With the help of optimization technology, the number of nodes required for WLAN can be minimized using suitable path. To identify the suitable path and overcoming most of constraint, optimization techniques as Genetic Algorithm (GA) or Particle Swarm Optimization (PSO) are used [28-30].

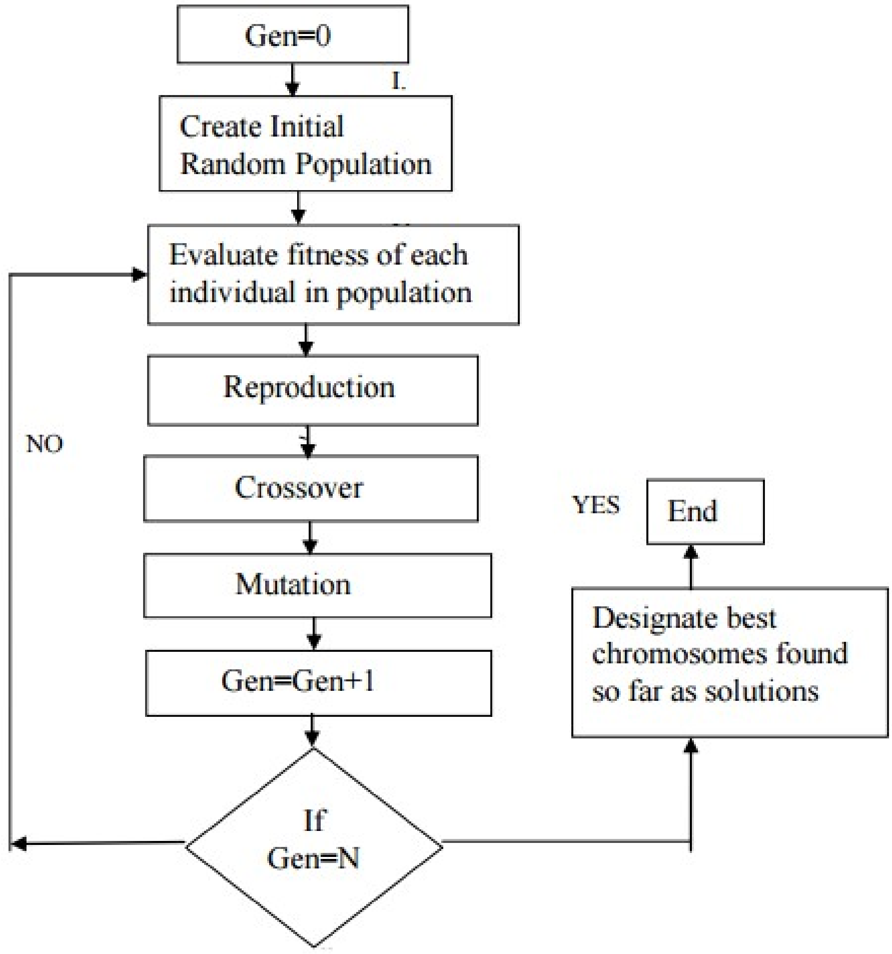

Figure 1.20: GA flowchart[31]

1.7.2 GENETIC ALGORITHM [31]

In 1970 John Holland proposed Genetic Algorithms (GA) as search and optimization algorithms which used the principles of natural evolution. Evolution of species with the help of natural selections is the strategy used by optimization techniques like Genetic algorithms.

Genetic algorithm is based on Darwin's theory of evolution which work on the rule, 'Survival of the Fittest'. As per Darwin's theory, the new modules of living things exist through the progression of alteration, crossover and reproduction amid existing organisms. The GA search technique is theoretically built on the 'Mechanism' of 'Natural Genetic and Evolution'. The GA was proposed to initiate the number of population candidate. The population candidate obtained randomly within the viable area which is encoded in binary strings which effectively form chromosomes. The population was decoded with whole numbers that lead through the evaluation process.

Selection, Crossover and Mutation are the three main genetic operations. With certain configuration that merge the two different parent chromosomes to create two new different offspring chromosomes. These newly formed offspring chromosomes have different characteristics from initially used parents. These offspring chromosomes are applied in an operation of Crossover. As soon the new population is produced with the help of selection and crossover operations, the mutation operation will be applied with minor probability.

Operation mutation is applied with intention to obtain additional information from the population which will not be able to continue with the parents. GA is a parallel and global search technique that can take care of optimization problems with non convex and non smooth objective functions The obtained algorithm can be applied on eight processors. The major disadvantage of GA is longer premature convergence and longer computation time.

The GA follows the following steps (Fig. 1.20).

1. Initialization: In most of cases Genetic Algorithm start with an early population which is randomly generated. To produce a better quality early population, lot of research work has been already involved. It give the GA a better start and fasten up the evolutionary process.
2. Selection: Two parent chromosome are chosen from the population. The chances of being selected increased as the better fitness.
3. Reproduction: - The nest step of selection is reproduction using chromosomes. Two chromosomes are selected according to present selection procedure and then by performing crossover on the desired function to generate one or two children. The result may be used again into the population, and mutation also can be applied if required. The population with least fit of population automatically get destroyed.
4. Crossover: Crossover is used to form a new offspring (children).
5. Mutation:-After a crossover, mutation is performed. Mutation is a genetic operator which act as tool used to ensure to maintain genetic variety to from series of generation of a population of chromosomes to next.
6. Replacement: The new generated population are replaced for a further run of algorithm.

1.7.3 PARTICLE SWARM OPTIMIZATION[32]:

Kennedy and Eberhart are the first to propose this technique, which is founded on stochastic search optimization technique based on population. This method was named Particle Swarm Optimization. PSO is stimulated by fish schooling or bird flocking's social manners. The optimization problem are solved by using a portion of wide group of

Swarm Intelligence methods. PSO is algorithm based on population, in which each solution is 'referred' as particle. Every single solution is referred as 'candidate' solution. In this method, every particle flies through the 'search space' and each one possess flexible velocity. This flexible velocity later can be dynamically modified subject to their distinct flying experience.

It also involves the flying experience of other particles. Every particle strives to improve themselves, through reproduction using their successful peer's traits. During the progression, every particle possesses 'memory'. As it possesses memory, it is able to retain the best position in the search space, The best fitness corresponding matching position is nominated as *'pbest'* and the best in the total from all participating particles in the population is nominated as *'gbest'*.

$$\nu_{j,g}^{(t+1)} = \omega.\nu_{j,g} + c_1.r_1(.).(pbest_{j,g} - x_{j,g}) + c_2.r_2(.).(gbest_g - x_{j,g}^t) \tag{1.1}$$

$$x_{j,g}^{(t+1)} = x_{j,g}^t + \nu_{j,g}^{(t+1)} \tag{1.2}$$

With *j = 1,2,....n* and *g = 1,2,....m*
Where,
n = number of particles participated from the group;
m = number of members in a particle;
t = number of iterations (generations)
$\nu_{j,g}^{(t+1)}$ =Velocity of Particle *j* at iteration t,

$$\nu_g^{(min)} \leq \nu_{j,g}^{(t)} \leq \nu_g^{(max)} \tag{1.3}$$

ω = inertia weight factor;
c_1, c_2= Cognitive and Social acceleration factor respectively;
r_1, r_2= Random Numbers uniformly distributed in the range (0,1);
$x_{j,g}^t$ = Current position of particle *j* at iteration t;
pbest$_j$=pbest of particle *j*;
$gbest$=$gbest$ of the group
The j^{th} particle in the 'Swarm' is signified by a *g-dimensional* vector $x_j = x_{j,1}, x_{j,2}, \ldots, x_{j,g}$ and its velocity is denoted by other *g - dimensional* vector $v_j = v_{j,1}, v_{j,2}, \ldots, v_{j,g}$.

The best preceding position of the j^{th} particle is denoted as

$$pbest_j = pbest_{j,1}, pbest_{j,2}, \ldots, pbest_{j,g}$$

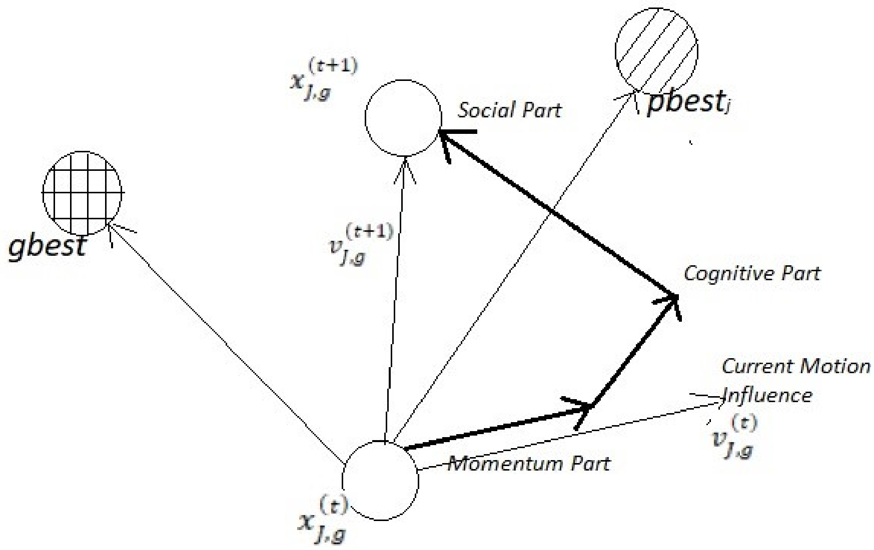

Figure 1.21: The position update of a particle for a two-dimensional parameter space.

The list of ‘best particle’ from all of the particles in given group is denoted by the *gbest*. For each particle‘s own preceding’s best position describes the velocity in search space. While describing the velocity, the group‘s preceding best solution has also been considered. In the PSO, the updated velocity can be described to be consists of three parts; described as momentum, social parts and cognitive. These three parts operates in balanced form to regulate the routine of a PSO algorithm. The parameters c_1, c_2 control the relative tug of *pbest, gbest* and the parameters r_1, r_2 help in varying the pulls stochastically. The iteration number in the above equations is represented by superscripts. PSO explore best solutions. Exploitation parallel swarm accommodates variety of particles. Every location of particles represents a key of candidate to the matter of optimization (Fig. 1.21). Every particle starts with a random rate and position beneath the attainable vary.

The fitness analysis operate is then used to allot the worth of particle fitness. The particle is assigned with simplest position among all particles and therefore the best position of every particle until this iteration is assigned. Each particle updates its position supported by his own finest position and therefore the best Swarm overall position is assigned at the previous iteration. PSO has effectively helpful to issues of worldwide optimization with each non-swish or non-protrusive functions of objective. In addition, PSO has established outstanding properties and is modest in its data and performance. All random optimization techniques as well as PSO, needs relatively an extended computation time as compared to most of the mathematical techniques.

1.8 MOTIVATION OF THIS RESEARCH

The primary motivation of the research was to improve the livelihood of the underprivileged residents of the remotely located villages. The residents of these remotely villages are unaware of technological developments and still living their lives under candle light. Not only this, due to lack of access to technological developments like electricity, they mostly remain underprivileged in terms of access to education, health and hygiene, information etc. and hence, they are away from the streamline civilians. Thus, millions of residents of these villages are forced to live 'underprivileged life'.

Most of these un-electrified villages are without electricity, due to various technical constraint. Electrical energy could not reach to these villages due to various extreme difficulties, as far off locations from grid, extreme geographical conditions, spare population, economically unviable, etc. Various solutions had suggested to electrifying these remotely located villages using renewable energy, particularly Solar and Wind.

Efforts were made to provide electricity by installing micro size 'Power Plants' using these naturally available sources and to provide an access of electricity to these villages.

However, these micro size plants could not prove to be long lasting solutions, as over a period of time power plants started facing technical problems, which were beyond repairable by local habitats. The skilled technical assistant was not available due to difficulty in access to these power plants. As a result, the Power Plants started being deteriorated and are finally stopped functioning.

The major cause behind the improper operation of power plant was lack of attention and maintenance. Local habitats are not aware of issue and technical expertise was not available.

If the technical expert is able to take appropriate corrective measures at the first instant, the situation would have been different and these systems then would have served the desired purpose for a longer duration. However, it was not practically possible to get the 'expert' help all the time due to extreme geographical conditions.

In this research work, a methodology will be suggested so that the expert can access the related parameters of the 'Power Plants' from a distance location and in case if any abnormal behavior is observed then the expert can take the required corrective measure to ensure the proper operation of the 'Power Plants. Such timely corrective measures will also prevent any further deterioration of power plant that can ensure long term operation.

1.9 OBJECTIVES OF THIS RESEARCH

Based on the motivation, in this research work a methodology will be suggested so that, the remotely located power systems can be monitored at a centralized location and based on the need appropriate steps can be taken. The objective of the research are:

(i) To optimize the 'communication path' with least numbers of 'communication nodes' so that the complexity of path minimizes and reliability of network increases.

(ii) To develop hardware circuit using sensors to scan the various operational parameters related to power system.

(iii) To develop an integrated communication network, that will consist of a short range communication network and a WAN.

(iv) To communicate parameters measured by sensor circuit through short range communication network or GSM and to display the parameters at the operators console at 'central location'.

(v) Path optimization will be carried out to overcome various constraint associated with data transmission as geographical obstructions, limit number of access points etc. Number of access points are optimized to limit the complexity.

1.10 CHAPTER SUMMARY

This Chapter describes the close association of livelihood and the electrical energy and how the livelihood of many remotely located villages has been affected due to lack of electricity.

The details of various existing remotely located power systems like Solar, Micro Hydro, wind etc. and their present operational condition has been discussed. Their status in terms of working condition, their designed rating, their present performance, the probable reasons for their under-performance or being not in working condition etc.

The Chapter describes the various operating parameters that needs to be monitored to ensure the healthiness of the remotely located power systems. In this Chapter, the integration of communication technology for the purpose of real time data monitoring has been discussed along with application of optimization technology to reduce the complexity in communication. Application of optimization technology to reduce the complexity of communication.

The Chapter also describes the proposed research work and the research methodology for the research work.

To understand the present technologies, it is required to carry out the available research work and literature survey. The literature work related to the proposed research work has been discussed in Chapter 2.

CHAPTER 2

LITERATURE REVIEW

A literature survey was carried out to understand the various work done in the related area of ‘remote control of power system‘ and ‘Path Optimization techniques‘. There were some review papers available in the area of Remote control of Power System and immense work had done for path optimization for various application. The various contribution in the related fields had mentioned in the reference section.

2.1 REMOTELY LOCATED POWER SYSTEM:

Our ancestors harnessed solar and wind energy for thousands of years now. Since 1300 BC, strong currents of winds were used to sail boats, which then brought the world closer and helped in exchange of ideas, knowledge, culture, trade, etc. bringing about overall development of humanity. Columbus, with the help of his La Santa Maria, discovered America in 1492. Solar energy was used for drying, and the first commercial use of solar energy was in desalination of seawater to produce drinking water. From the last 150 years, fossil fuels have become our primary source of energy due to high energy density and feasibility. However, unlike solar and wind energy (renewable resources), they are not unlimited, and lead to a lot of carbon emission leading to global warming and pollution. Technological advancement has now enabled us to feasibly harness the renewable sources of energy and easily convert them into electrical energy (the major form of energy). Due to all these reasons, it is time that we focus on tapping the renewable resources of energy and reduce the usage of fossil fuels.

H. Al-Badi et al. [33],The authors have proposed a cost effective model for remotely located systems. Due to increasing oil prices, hybrid renewable energy systems are feasible alternative for power generation. This paper provides a feasible solution by using wind energy in currently established diesel power plant at an isolated area in Oman named Al Duqm. Using the actual load and wind data at diesel price of 0.368 $/l it was seen that the hybrid system would be least expensive at minimum wind speeds of 5.3 m/s, which is very close to the average wind speed of the area. As the wind speed increases the cost decreases, and hence, this is a great alternative to the currently established diesel only power system

Shafiqur Rehman et al. [34,] in their study uses solar energy to produce a part of electricity in a village where it is solely generated using diesel. This can be done using a power system based on hybrid power system using Photovoltaic and Diesel engine assisted a battery backup. To find the optimal power system using solar, for the village, the feasibility study was carried out on hourly solar radiation basis at the site. Later based on the results, the PV modules were mounted on fixed foundations. Each module was assisted by diesel generators and different sizes of battery banks and converters. These measurements yielded that a PV array of 2000 kW and four generators of 250 kW, 750 kW, 1250 kW, 2250 kW, operating at a load factor of 70% running for different hours per year were required to produce the requisite amount of electricity annually. The cost of energy of diesel only was 0.190US$/kWh and for the hybrid system with 21% solar penetration was 0.219US$/kWh (diesel price being 0.2$ per liter). It was seen that at diesel price 0.6$ per liter, the cost of hybrid and diesel based power system is almost the same and above this the hybrid is more economical. The research work has helped in carbon reduction.

Md.Moniruzzaman Tanim et al. [35], in their paper authors have designed a hybrid Photovoltaic-Biogas power system for the electrification of remotely located village. Bangladesh is facing acute shortage of electricity, and renewable resources are a great solution. Potential of bio and solar energy at the desired site was checked using a software tool. Based on findings the authors have designed a PV-biogas hybrid power system to generate electricity. a television , Illumination, fan, and a refrigerator etc are considered as basic suggested load. Simulations and design were done using HOMER software.

Jahidul Islam Razan et al. [36], describes the effect of micro hydro power plants to over come the energy crisis. Some of the factors holding back the economic development of Bangladesh are depletion of fossil fuels and the inability to meet the rising demand of electricity. Bangladesh has many rivers and canals providing off-grid power to the remotely located villages, and hence, this paper focuses on the potential of micro hydro power plant to generate electricity and how widespread establishment of these can help in overcoming the power crisis and economic development of the country. Potential sites and the methods to identify new sites by performing head calculations, hydrology studies, topographic studies, turbine selection, etc. have also been outlined.

Getachew Bekele et al. [37] , designed a Photovoltaic Wind Hybrid Power Generation system for a Ethopian Remote Area. This paper reflects the design of a hybrid power system using wind and solar energy to supply electricity to the Ethiopian remote areas. After investigating the wind and solar potential by gathering data from National Metrological Agency (NMA) and analyzing it using HOMER, it was concluded that they have great potential and can be used to generate electricity using wind turbines with low cut-in speeds. lighting, water pumping, a radio receiver, flour mill, and medical equipment at the clinic are the basic suggested electric load. HOMER is used for all the simulations and design and the results are power systems in ascending order of cost. The sensitivity variables entered were range of wind speed, solar radiation, PV panel price and diesel price.

Minna Ranjeva et al.[38], suggested an optimized solution for remote areas. This research is focused on creating a tool, names HYPORA (Hybrid Power Optimized for Rural/Remote Areas), that would determine the best combination of biomass, solar, and wind energy to meet the load demand at a location by allowing the user to input the specifications of various models and then analyses the cost to give the least expensive model and also the various ways in which the load can be met. Along with scientific basis, it will also take into account economic and need factors and government incentives. This is a Microsoft Excel bases tool and can be used by anyone due to its user friendliness. The intended feature of this tool is that, it consider technical features as primary requirement, however, the optimization will be done considering some other parameters also like Cost analysis, Govt. incentives etc.

M Halawani et al.[39], have discussed a unique micro grid, which is fed by four various sources Solar, wind, diesel and battery bank. The paper also discusses about the socio economic effect of renewable energy in counties like Jordan. Purpose of battery bank is to improve overall grid performance and reliability. The authors have simulated system using MATLAB to find the stability and reliability of the power flow balance. The author has proposed to use fuel cells as battery bank.

Okeolu Samuel Omogoye et al.[40], The paper reflects design, simulation, and optimization of a hybrid PV-diesel power system to meet the electrical demands of a remote location. After determining the total energy demand and the solar radiation data, the information was used to size the components (number of solar panels, deep cycle batteries, and inverter rating) and determine the configuration using HOMER. After careful technical and cost analysis, a suitable generator was also selected. Assuming a 25 year life expectancy, the analysis shows that this hybrid system is an economic solution to meet the electrical demands.

Prawin Angel et al.[41], in their paper titled, Design of 15 kW micro hydro power plant for rural electrification at Valara have described use of micro hydro plant for rural electrification. Due to the fast depletion of natural resources and the difficulty to connect to the national grid, the best solution to supply electricity to remotely located villages would be by using the natural resources available at the site. This paper attempts to electrify one such village, Valara, located in the Idukki district of Kerala in southern parts of India. After careful examination of economic and technical feasibility, it can be concluded that a micro hydro power plant is a great method to meet the electrical demands of Valara. The review of various research work, indicates the efforts are made towards electrification of remotely located villages with the use of renewable energy or hybrid systems.

2.2 DATA SENSING FOR REMOTELY LOCATED POWER SYSTEM:

The literature in the previous section discusses about the power systems located for remotely located areas. As discussed earlier, it is also equally important to ensure the proper operation of these power plants. The healthy operation of the power plants can be ensured, by looking at the operational parameters of power plants. The measurement of parameters and monitoring of the same is a key requirement. Thus, the Data sensing is one of the most important parameter for any experimental work. Various papers have been studied for data sensing which are described here.

X. Chen et al.[42], described the importance of remote monitoring and associated research. Data acquisition and transmission plays a vital role in the field of modern manufacturing and production control. Most of the time the data handling and processing is done at a central location which is far away from the production unit. Over a period of time is has been concluded that wired communication is just not good enough for data transmission due to low insulation and manually recurring faults. In the present system a novel technique of acquiring, filtering and analyzing data by GPRS technology had been proposed. The results of the experiment carried out reveal the system work with higher efficiency for data capture and communication based on GPRS technology.

Xia et al [43], published earlier work in their paper; they outlined another water natural checking framework in light of remote sensor systems, which is appropriate for the perplexing and huge scale water condition observing. The framework in their work is made of three sections namely information checking hubs, information base station and remote observing focus. Information observing hubs in the checking system are in charge of seeing, obtaining, preparing and exchanging the water condition parameters. Author look into the low-control information checking hub in light of ZigBee remote innovation, and build up its equipment and programming. Diverse water quality sensors can be introduced on the hub so as to meet the constant observing for an extensive variety of water condition parameters including turbidity, electrical conductivity, etc.

A critical application of ZigBee based sensor tools has been demonstrated by Liu, Y. et al.[44], for patient monitoring in insolation. Two unconventional methodologies for the implementation of ZigBee based network for the remote observation of patients are proposed here and there recitals rate in a simulation milieu. The first tactic uses a single WPAN for communicating functional data from the patient.

The second tactic involves multiple WPAN for the single patient updates. In this case a WPAN will be given to each patient. The result revealed that multiple WPAN working is more efficient and effective than single WPAN.

Asmara et al[45], in their paper introduces a remote water level caution framework created by applying fluid sensors using GSM innovation. Framework center around observing water level remotely and uses GSM based SMS to pass on information from sensors to the individual clients over their mobile cellular phone. The equipment of the framework incorporates Micro Controller Unit, three fluid sensors, inverter and GSM Module. Programming utilized for the framework is compiled through AT charges. It is trusted that this undertaking would be advantageous to the network and would go about as a careful step, if there should be an occurrence of surge debacle at any surge inclined zone. By having early discovery, clients could make quick move, for example, evacuate the location to avoid loss of life

In the present work Yang et al [46], had developed a ZigBee or GPRS based technology for communication of signals in isolated locations, above all the date could communicated for longer distance effectively. Any atmospheric calamities are taken care by an inbuilt alarming system.

The post implementation study of Li Wang.[47], in their paper displays the after effects of outline, establishment and field estimation of a model submerged turbine-generator-based small scale hydro (MHP) control framework. The examined MHP framework utilizes the streaming water vitality of the horticultural water system from one of the water system trench of Yunlin Farmland Irrigation Association, Taiwan. Generally, the water system trench is utilized to provide the water to various farmlands. Outline of a MHP needs to meet pragmatic states of the chose jettison; for example; profundity, width, water stream rate, long stretches of water streaming, and so on. The composed MHP unit comprises of a model submerged turbine, a gearbox, a three-stage self-energized enlistment generator. Also it has a switchable excitation capacitor bank, a triple stage diode rectifier, a DC buck converter, and an inverter. An installed framework based observing and control arrangement of the MHP unit is additionally appropriately intended to quantify the electrical information of the MHP framework. As indicated by the field estimation, the outlined model submerged turbine-generator-based MHP framework can steadily offer sufficient electric capacity to the associated loads.

‘A Study of Control and Management in Solar Photovoltaic Power Plants and Remote

Measurement‘ by Lin-Yue Gao et al. [48], has described the about the remote measurement of Solar Photovoltaic systems. The authors have focused to implement the design of control and measurement of small solar photovoltaic power plant, illustrate their working principle and structure. Emphasis has been given on the design of component and circuit.
Data logger and storage was proposed by; Hunar et al [49], in their paper introduces the propose of the use of GSM remote data logger at small capacity hydro power generation station. Typically, sustainable power source control age framework requires the utilization of information procurement. Information securing of intensity, voltage, momentum, sedimentation, water flowrate and amount of water are regular information expected to assess execution. The vital electric supply is arranged by these lines to the matrix TNB station and give power to social occasions. Access to Small Hydro Station is found difficult to reach region that is 2.07 km statures and 3.44 km separation by course from powerhouse. There is no dynamic GSM line supplier at the territory. Thus, the advances in correspondence , for example, radio recurrence gadget offers new conceivable outcomes of effective information exchanging. DT80M can send information, utilizing GSM frequency from remote territory.
Khera et al [50], in their paper points in building up a basic remote information framework for condition observing of the process. The physical parameters are observed using a basic data acquisition card and transmitted the obtained data to the remote administrator. The dim condition is detected for the light power esteem below 120 Lux and at this point an additional light source circuit becomes either turn on or off. Speed control of fan is done based on PWM and in view of the temperature information procured. The principle target of this work is to make a nonstop data getting structure and to persistently impart this data to the android tab and over the web from the virtual condition of LabVIEW. The obtained information esteems are additionally constantly logged and put away in database document at the hard plate of host PC to facilitate examination.
Haider-e-Karar et al. [51], in their paper ‘Solar power remote monitoring and controlling using Arduino, LabVIEW and web browser‘, have described about the use of modern technologies in control of remotely located systems. The paper has proposed use of graphical user interface (GUI) to real time control and monitor of the Electrical power generated by solar panels. One data monitoring server has been installed near to power system for monitoring and controlling at the location while the client GUI can be accessed by using a web browser globally by authorized person to monitor and control all operations. The data monitoring server and client GUI are developed by using LabVIEW and LabVIEW UI builder while hardware is developed with Arduino Uno, current and voltage sensors, relays and charge controller.

2.3 WSN FOR REMOTE DATA COMMUNICATION

The remotely located power systems may not be in the vicinity of the communication network, in these cases it is not possible to transmit data to the centralized control center. The research work proposes to integrate various communication technologies in various topology to communicate data to the nearest globally available GSM/CDMA network. The literature survey proposes integration of two technologies for the purpose of data transmission from the remotely located power stations to the centralized control center, where data can be monitored and to take appropriate measures as and when required. Various papers were studied based on various technologies and their applications. Some of these literature reviews are outlined here.

Korkua et al [52], discussed that a novel remote information gathering for wellbeing observing arrangement of electric machine in view of remote sensor organize. ZigBee is proposed and created in their paper. The remarkable qualities of ZigBee systems, for example, low power, ease, and high adaptability make them perfect for this application. As the focal point of this paper, the equipment plan and execution of a various hubs ZigBee based remote sensors are examined. The correspondence convention and programming outline for both remote sensors organize hub and construct station based with respect to the CC2430 framework on chip are displayed in detail. Test aftereffects of the proposed remote sensor organize for its relevance to explore distinctive working conditions, for example, electrical deficiencies and mechanical shortcomings are researched and examined.

The proposed system by Zengyou, S. et al. [53],is designed based on ZigBee and GPRS for efficient electrical power monitoring system. The device uses CC2430 as the ZigBee component and the planning and monitoring terminal nodes based on ZigBee. The device uses a wireless GPRS remote broadcast. The device is a financial boon and decreases complexity of fabrication and has wider applications.

Hubert et al.[54] developed a low cost high-voltage overhead power distribution system plays vital role in power transmission at the same time there are some cons like linear expansion of conductors which may lead to lack in safety and limit the workability of the system. High capacity may also lead to physical damage. By having a live monitoring mechanism vital states can be identified at the right time and recovery measures can be taken. In the present work we are working on opportunities for measuring devices that can be fixed on to the probe. The device can be power by the electrical field and also the low voltage circuits can be shielded from strong electric field as established in this work. Also the device is workable under heavy magnetic field.

Luan, S.W. et al. [55], presented a paper on smart meters. Globally governments allot pervasive IT projects, with an aim to merge state of the art wireless network and wide-band technologies etc. to accomplish a pervasive wireless communication system. The ubiquitous wireless communication network can be engaged for the Advanced Metering Infrastructure (AMI). In the present work we have used the latest in wireless communication to design and install a ZigBee based intelligent power meter. A recording system is also designed and embedded into the smart meter. A ZigBee system is devised and assimilated into the system. The system is designed using a microcontroller of Microchip dsPIC30F series. This smart device will be used to transmit the detailed power consumption data and outage event data to rear-end processing system. The smart system is potentially equipped to be used to build the area-based AMI. Experimental results support the designed smart system.

Devidas et al. [56], focused on wireless smart grid monitoring. The electrical transmission and distribution losses are very high in India and vary between 30-45%. for monitoring and optimizing the electric transmission and distribution system in India it is necessary we have a wireless network based design. The system consists of multiple intelligent devices like wireless transformer sensor node, controlling station, transmission line sensor node, and wireless consumer sensor node. The developed software module integrates data accretion algorithms used for different pathways of the electricity distribution network. The design involves active solutions for various constraints in Indian electrical distribution network i.e fluctuations in voltage due to unpredictable electrical consumption, power theft, manual billing mechanism and transmission line defects. The developed design is for single phase electrical distribution network. The design is also suitable for 3 phase system with minor developments. The installation of this design lead to low loss in transmission network and thereby availability for more consumers. The developed design is efficient in Indian context for delivering for continuous real time monitoring of energy usage, with minimum loss and better fault detection and billing automation.

Alessio Carullo et al. [57], in their paper the work involves metrological supervision of a data collecting system that has been fostered for monitoring and investigate photovoltaic (PV) plant. The system has been derived for comparing the working of various PV technologies and for corroborating the minimum specifications of the PV modules. The module should be periodically calibrated for vestige error free monitoring system. A remote procedure is developed and proposed for the calibration of the acquisition system. The calibrator has a potential to perform as a reference for heterogeneous parameters which include electrical information, temperature and solar irradiance. The design of the calibrator is described and the experimental results for the characterization of prototype have been discussed.

Zhang, Q.[58], at presented research work, With an aim to control and supervise smart grid, ZigBee technology were adapted. ZigBee technology and smart grid have potential applications in smart Han, defect identification and ultra-high voltage transmission line study. ZigBee application for smart grid have been proposed in the present work. ZigBee technology amalgamated with smart gird progressively and become an imperative wireless communication technology.

While, Jiang and others [59], in their paper initially sketched out the current circumstance and advance on wetland water condition checking innovation. It proposed a remote sensor arrange based ongoing checking framework utilizing computerized video and depicted the planning plan and framework engineering. It additionally exhibited in detail the highlights and planning approaches about; ZigBee remote innovation based information observing hubs, computerized video construct stations based with respect to ZigBee and CDMA remote advances, water ecological computerized video checking focus, and so on.

Feng et al [60], discusses the utilization of vineyard's dry spell, using a remote wireless sensor network (WSN). Detecting hub was customized with a locale a WSN in vineyards. Each detecting hubs was made out of a miniaturized scale processor for information handling and controlling, advanced sensor modules for information estimations, and RF handset module for information transmission and gathering. In-field organizing tests were led in 5 diverse hub arrangements in light of hubs thickness. The normal estimations of bundle misfortune rate under various situations were varied from 0.96% to 14.83%. Results demonstrated that the framework can gather the temperature, mugginess and soil water content, and transmit information remotely to the base station, gave the attributes of working solidness and unwavering quality.

Kim et al. [61], presented application of ZigBee for home automation. Smart home technology is a boon for energy saving. In the present work based on remote sensing network an energy management system is proposed by kim et al. the system is serene of two main elements: A remote wireless sensor linkage and a smart home access. The electrical data is transmitted through wireless device remote checking and regulate of home appliances are provided by smart home access to users. The system enables user to save energy by smartly checking and regulating the appliances at home sitting anywhere through internet services.

Wang et al [62], discussed that sensor hubs and the remote handset module utilize center chip of cc2430, to construct remote sensor systems in view of ZigBee convention. The outcome demonstrates this framework has stable execution, and can meet the planning prerequisites. Execute of the framework is anything but difficult to adaptability send; it rearranges the establishment of gear successfully and make it more reasonable for nursery natural information checking needs.

2.4 OPTIMIZATION TECHNIQUES IN WSN

As discussed remotely located power systems can be ‘truly remote‘. In most of cases, accessibility to these power stations is very challenging. As per previous discussion, even integration of two or three technologies may also be required with multiple access points, receiving and transmission stations with complex topology. The hardware mechanism may provide a solution for these. But, as the access points increases the other complexities like maintenance of notes, safety of nodes, power requirement to nodes goes in multiples. The research work also proposes for the path optimization for the data transmission from multiple nodes/power stations. In this regard, various literature survey was carried out for the path optimization.
Frank Ivis [63], of Canadian Institute for Health Information, Toronto has described about the concepts and methods for calculating Geographical Distances. In his paper titled, ‘Calculating Geographical Distance: Concepts and Methods‘, published in NESUG 2006, he has descried the important component of calculating point to point distance. Though the specialized software are available, to measure the distances, and in this approach the need can be customized as per the need.
Shammah and Ela et al [64], paper shows a method to research the issue related with the ideal area of remote terminal units (RTUs) inside appropriation systems. The RTUs empower checking distinctive areas, which are connected to the local control room (LCR) through a correspondence framework. The multi population genuine coded hereditary calculation (GA) is utilized as an advancement strategy to choose the ideal areas of RTUs. The target work in the advancement strategy is to limit the aggregate cost including the capital expenses and the running expense. The ideal area of the RTUs depends on the heap compose, stack limit, level of voltage drops and disappointment rate. A piece of the Egyptian circulation arrange is utilized as a genuine test framework to demonstrate the legitimacy, ability and effectiveness of the proposed method. A genuine system is picked since it is proposed to actualize the acquired outcomes in the genuine circulation framework. The capital expenses of RTUs incorporate introducing and migrating.
On the similar note Jovin j Mwemezi and Youfang Huang [65], of Shangai Marintime University, China has also described about the optimization of location on spherical surfaces in their paper titled, ‘Optimal Facility Location on Spherical Surfaces: Algorithm and application‘, for New York Science Journal in 2011. The approach is to apply fundamental method of Rectilinear and Euclidean distances approach to obtain great circle distances. This approach helps to obtain the Arial distance over Earths spherical Surface.
Shammah et al [66], proposed analyst‘s method to examine the issue related with the ideal area of remote terminal units (RTUs) inside dispersion systems. The target work in the

streamlining method is to limit the aggregate cost including the capital expenses and the running expense. The capital expenses of RTUs speak to introducing and moving RTUs. The ideal area of the RTUs depends on the heap compose, stack limit, level of voltage drops and disappointment rate. This paper shows a proficient ideal proposed procedure to move the RTUs utilizing the GA. The GA has been effectively connected as a streamlining strategy to limit the general cost, thinking about various specialized components. The general cost incorporates the capital cost of RTUs and the running expense of the client and utility expenses. The ideal area of RTUs has been acquired keeping in mind the end goal to limit the aggregate expenses of the framework contrasted with the underlying circumstance of RTUs with and without considering the client interference cost. The power stream computations have been performed utilizing the ETAP bundle.
'Effective technique for allocating servers to support cloud using GPS and GIS'[67], presented in IEEE conference, 2013; by Ayad Ghany Ismaeel has described use of Havrsine formula to select the sever as back up for cloud. For effective and reliable communication, the healthiness of server is crucial requirement. Failure of a key server can severely cause the disturbance. In such case of failure of a key server, it is important to made availability of backup server. However, back server at each location will require huge investment. In such case, in the event of failure of the main server, a nearby (lightly loaded) server can be used as back up server. The author has used Haversine formula to calculate the distance between servers and select a most suitable server as backup server.
Rajib Chandra Das et al.[68], have proposed a model to provide emergency medical service during road accident. Authors have used 'Opensteermap' and located all the medical services in the specified zone. In the event of need of any emergency medical service, the model developed will calculate the distance between all the medical services and the location of accident using Haversine formula and based on the minimum distance, the medical facility has been identified.
In their paper, Cecep Nurul Alam, Khaerul Manaf, Aldy Rialdy Atmadja, Khrisna Aurum [69], of State Islamic University Sunan Gunung Jati Bandung, have also described the use of Android app to identify the location to control movement. The paper titled, 'Implementation of haversine formula for counting event visitor in the radius based on Android application' presented in 4th International conference on cyber and IT service management at Bandung, Indonesia. Location based services (LBS) helps to gain a position in the geographic presence of GPS device. Haversine formula has been used to calculate the distance from two different coordinates on the earth's surface. The Authors have used Haversine formula to calculate the distance used same to determine the number of visitors who signed into events. In the paper titled, 'Shortest Path Calculation: A Comparative study for location-based recommender System'[70], 2016 World Symposium on Computer

Applications and Research (WSCAR), Hagar Mahmoud ; Nadine Akkari have described the comparative study of location based services, which uses Haversine formula.
Tareq Monawar et al.,[71], in their research work used vehicle tracking and GPS to identify the location of vehicle in case of it is lost of theft. In the event of any suspect about the lost of theft of vehicle, the owner of the vehicle can send a SMS to the antitheft system installed on the vehicle, which is password, protected. As soon as the antitheft system receives the secured SMS from the owner, the antitheft mechanism send the location of vehicle. Then with the help of Haversine formula, the distance between the owner and the exact location can be calculated, through which nearest police station can be identified. Thus, the system can prevent the theft of vehicle.
The research work of Mladen Knezic [72], is with objective of Response time Optimization. With upcoming industry era of 4.0, the competency plays a giant role to keep in leading. With technological advancement, AI, robotics, IoT, networking create a virtual world. Synchronizing among all is key requirement. The researcher has carried out the practical analysis of real time ethernet. Based on the priority and performance of the task, the time management has been achieved.

2.5 SUMMARY OF CHAPTER

The various papers has been reviewed and the update of the various existing methodologies has been summarized in this chapter. The research work related to remotely located power system describes the various small-scale power plants using renewable energy technology. The papers discusses about the operational issues, reliability issues related with the small-scale power plants.

Other research papers discussed about the various research work in the area of remote sensing. Authors have used various techniques, using communication technologies. Wide applications have been described for sensing and monitoring data. The literature survey related to real time data monitoring are limited to monitoring and sensing data for a particular system and data has been communicated using single type of communication technology.

The research papers related to optimization have described the numerous application of optimization process. The adaptability and acceptability of Optimization techniques is seen most of applications including business, technology, finance etc. In some of the research papers, optimization techniques are used for path finding. The most of the research work describes the optimized path between a source and destination points. The comparison of various technologies also has been described in the research papers. Some of the research papers have described the use of Haversine formulae to estimate distance between two locations or to identify the GPS coordinates of specific location. The most of research work was focusing on the point to point communication. The major shortfall of the presented research work, was to identify the shortest distance path with minimum nodes from multiple points to a single points.

The outcome of the literature work can be described as research work has been carried in the area of micro power plants, data sending, real time monitoring, path optimization etc. However, there a need of research in developing a low cost sustainable communication network with integrated technology for the real time data monitoring of remotely located systems.

In view of the in this research work, it is required to suggest a suitable methodology to optimize path for the real time data communication from the remote location to the location where WAN is available and then implement the hardware for data sensing and communication.

The research work, shall propose a methodology by developing an algorithm for path optimization with multiple location and considering geographical constraint as mountains, extreme forest etc.

In the next chapter, an algorithm is developed to communicate the data from multiple points (locations) with minimum number of nodes to a central location. The validity of the algorithm will also be verified using a practical case study to the villages of Uttarakhand.

CHAPTER 3

OPTIMIZATION

3.1 POWER MONITORING FROM REMOTE LOCATION

Monitoring of power and its proper management plays an essential role in today's world. However, this becomes a difficult task when the target area is at a remote location. Monitoring a remotely located power plant from a long distance and managing the distribution of power and cost effectively is a major challenge. This becomes even more challenging if WAN is not available at these locations.

In this research work, a system is developed to communicate the data from these remotely located power systems to the main location (where WAN is available) by creating a WLAN.

To properly communicate data (power plant parameters), a Wireless Local Area Network (WLAN) will be created using short-range communication technologies (Table 1.10). The major advantage of most of the short rage communication technology is that, they are 'freeware' technologies. However, as their name indicates, they can transfer the data over 'short distances' only. If the location is far off from the place where WAN is available, then we need to use multiple devices in series, which further increases cost and complexity.

LWAN can be created using single (freeware) technology or by integration of various (freeware) technologies. In this research work, ZigBee is selected as communication technology, to develop LWAN. Based on the distance between source and destination location, a communication network of many ZigBee nodes (ZigBee transmitters/receivers) is created as shown in Fig. 3.1.

If the distance increases, the numbers of ZigBee nodes required increases. For each node to make it functional, it is required to arrange for power supply, safety, designing hardware, programming etc. Hence, as the numbers of ZigBee nodes increases, the complexity during installation and later during operation increases. Thus, the objective of this research work is to minimize the number of nodes with the help of optimization to reduce the complexity of network and improve the reliability of system. In this research work a

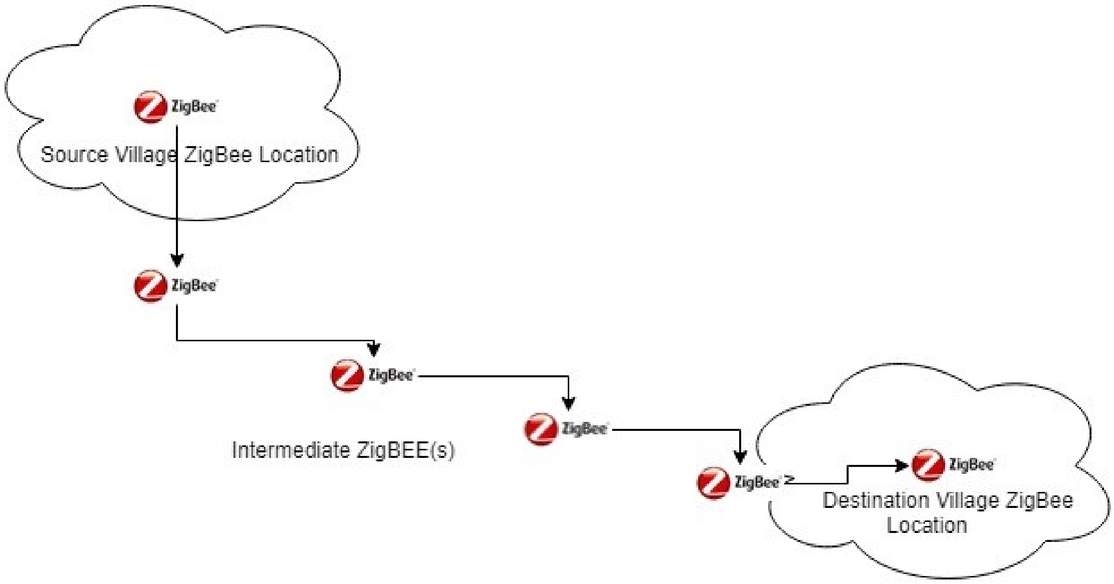

Figure 3.1: Indicative ZigBee network

new algorithm is developed with the help of Haversine Formulae to minimize the number of ZigBees. Hence, in this research work, a system is developed to optimize the number of nodes to minimize installation and operation cost and to increase the reliability of system [73].

The data transfer network discussed here includes collection of data from remote located power system and communicate the same through intermediate ZigBee's to the ZigBee(s) located at destination location. The ZigBee located at destination location will transfer data to the WAN network device, in this case GSM communication device, GSM Module. The GSM device, will communicate data globally and thus the data related with remotely located power system is now available globally (Fig.3.2). This data will be received at the centrally located control room, through GSM Module and finally the operating parameters of the remotely located power plants will be displayed on operator's console. It is general practice that, the centrally located control room may be the nearest major place/town/city to the remotely located system.

In this research work, an algorithm is developed to optimize the path (Fig. 3.2). The algorithm developed also gives the exact GPS coordinates of ZigBee for installation.

The data communication distance can be very long and, also, there can be various geographical and technical constraint that may obstruct data transmission. In this situation it is challenging to identify the exact location (coordinates) for the installation of node. The algorithm developed in this research work, will also consider various constraint, like geographical limitations while finalizing the GPS coordinates [74,75].

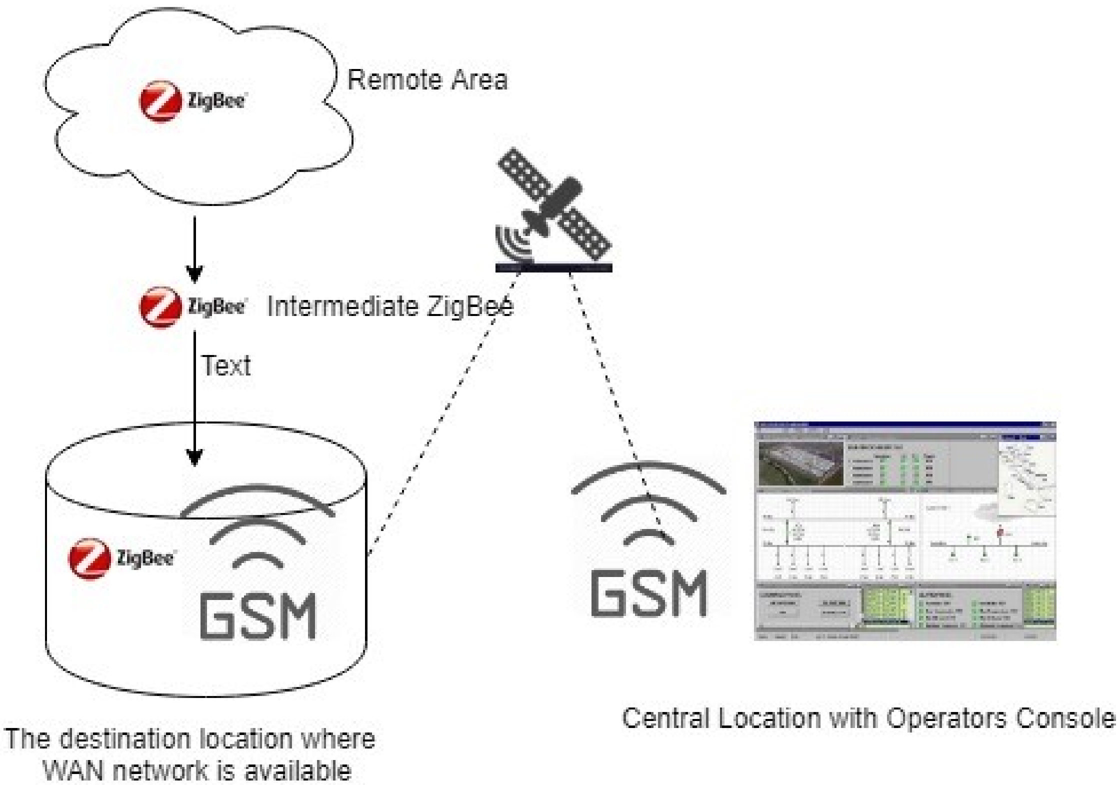

Figure 3.2: The complete communication network

Thus, the algorithm developed in this research work, will optimize the path, minimize the number of communication nodes requires and exclude all coordinates (GPS locations) where installation of ZigBee is not possible due to geographical constraint. For example, if result of optimization is a GPS coordinate, where installation of ZigBee is not possible, then algorithm will search for next Best location.

The objective of this research work is to develop a WLAN for communication with minimum complexity, which in turns results in maximum reliability. The WLAN developed should be cost effective and reliable also. The cost and complexity will decrease if there are minimum 'operating nodes' in communication network. To minimize the 'operating communication nodes' the primary step is to optimize the path from these extreme locations to destination location.

3.2 OPTIMIZATION IN REMOTE MONITORING

For the purpose of optimization, an algorithm is developed to meet the need. The Genetic algorithm (GA) and Particle Swarm Optimization (PSO) are used for it. In this research work codes for the Optimization are written in MATLAB R2014a. Initially the algorithm is applied to a fundamental problem and the same is applied to a real time problem considering five villages from state of Uttarakhand.

3.2.1 GENETIC ALGORITHM

Nature is the great source of inspiration for mankind. GAs are based on Darwin's theory of evolution that is "survival of the fittest", which describes the idea of competition to survive and reproduce, in nature. I. Rechenberg suggested the concept of evolutionary computing in the work "Evolution strategies" (Evolutions strategies in original) in 1960s. The idea was proposed by J. Holland and his students as the GA, which replicates nature's way of developing most successful organisms. This result to Holland's book "Adaption in natural and artificial systems" published in 1975. After the publication of D. Goldberg's book in 1989, GA became very popular. Since then the GA is being used by many researchers, where optimization is needed. GAs are implemented as a computer search in which population is represented as chromosome and each element of chromosome called as genes where as solution are individuals or creatures and optimization problem evolves toward better solutions. In general the representation of solutions is in binary form as strings of 0s and 1s.

To mimic, the biological evolution process can be dealt easily with Genetic Algorithm (GA) and genetic programming. The GA is based on search technique to find optimum or near optimum solution in search problems. In the process of evolution, GAs use the various genetic operators such as mutation, selection and crossover as problem solving strategies and categorized under global search algorithms.

3.2.1.1 GA - MOTIVATION

The older AI systems break easily if the inputs are changed, but GA is more robust and is stable even there is slight changes or in the presence of reasonable noise. It is also very helpful in searching in case of large state-space, multi-modal state-space, or n-dimensional surface over the conventional search algorithms.

Some attractive features of GA are:

1. Capable of Solving Difficult Problems

   There many complex computation problems, generally referred as NP-Hard problems, which takes very long time even with powerful computing systems. To solve such problems in short time with optimum or nearoptimum solutions GAs are prove to be an efficient tool.

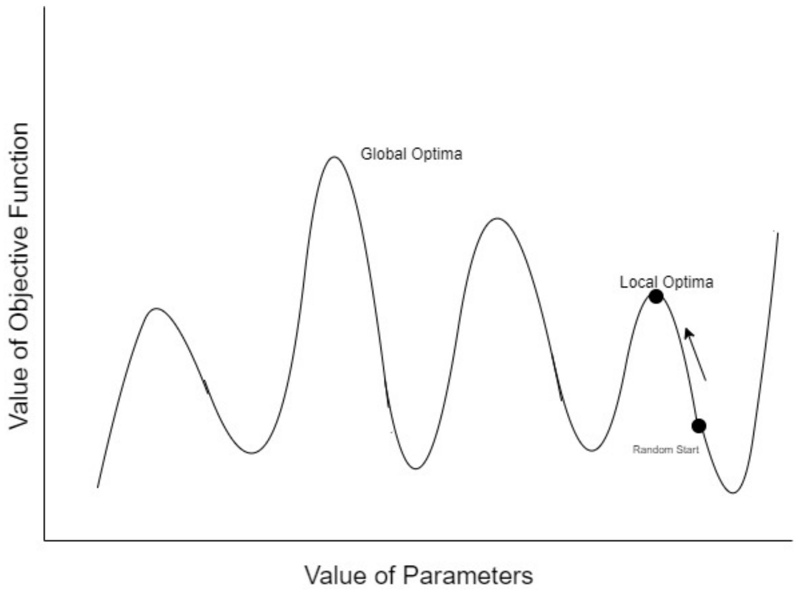

Figure 3.3: Optimization process

2. Limitations of gradient based methods

   To find the optimum point, in single peaked objective functions, traditional methods such as calculus based methods are also used. The process of optimization stars at a random point and reach to the optimum point that is top of a hill (near-optimum solution) by approaching towards of the gradient. However, most of the real-world situations are complex in nature. A function which has many peaks and many valleys, the gradient based methods are failed because it has limitations to get trapped at the local optima point, which is represented by Fig. 3.3.

3. Faster Solution

   The problems like the Salesperson, Delivery boys uses GPS navigation system to find the optimum path. To estimate the "optimal" path from source to destination is a practical field application and in calculation of path delay is not acceptable. Therefore, near optimum solution, which is to be delivered fast is required and GAs can play the role.

3.2.2 PARTICLE SWARM OPTIMIZATION (PSO)

Population based Stochastic technique for optimization, Particle Swarm Optimization (PSO) was developed in 1995 by Dr. Eberhard and Dr. Kennedy . PSO is motivated based on social behavior of fish schooling or bird flocking.

In PSO, every particle attempt to improve themselves, by process of reproduction using their successful peer's traits. The particles attempt to get best fitness, which are nominated as '*pbest*' and the particles, which is best among the population of all particles is nominated as '*gbest*'. The individual best, '*pbest*' and the group's best '*gbest*' of the previous solution decides the velocity to move in search space, for each particle. In PSO Momentum, Cognitive and Social Parts are the three parts, which decides the velocity update. We can Judge, the performance of designed algorithm for PSO based on the balance among these three parts. The position update for two dimensional parameter space and Velocity updates of the particles are already described in Fig. 1.21.

3.3 APPLICATION OF OPTIMIZATION IN POWER MONITORING FROM REMOTE LOCATION

3.3.1 PROBLEM STATEMENT

In this section, it is discussed how is the optimal position of ZigBee modules is identified using Optimization. Graphical representation of the scenario is shown in Fig. 3.4. Data is collected from the three different locations which are far apart from each other in different directions. The data is to be sent to a GSM network through a centrally placed ZigBee(s).

ZigBee has a range of 1 km so it can be placed anywhere in the circle of 1 km radius with the GSM as the center. Now, the optimum point on the circumference of the circle would be that point, which gives shortest of the distances from all the 3 locations. This optimum point is selected using results of optimization.

3.3.2 OPTIMAL PLACEMENT OF ZIGBEE USING GENETIC ALGORITHM

In optimal placement of ZigBee, the coordinates on the circumference of the circle, which indicate the periphery of the GSM with ZigBee are the variables and the objective is to find the minimum distances from all the '*n*' locations to that coordinate. Fig. 3.5 illustrates the procedure of optimal placement of ZigBee using GA. Application of GA for ZigBee placement is described as following:

Step I Representation: Let the chromosome *X* is denoted as $X = \{x_1, x_2\}$, where where x_1 is the longitude of the coordinate on the periphery of the GSM and x_2 is the latitude of the coordinate on the periphery of the GSM.

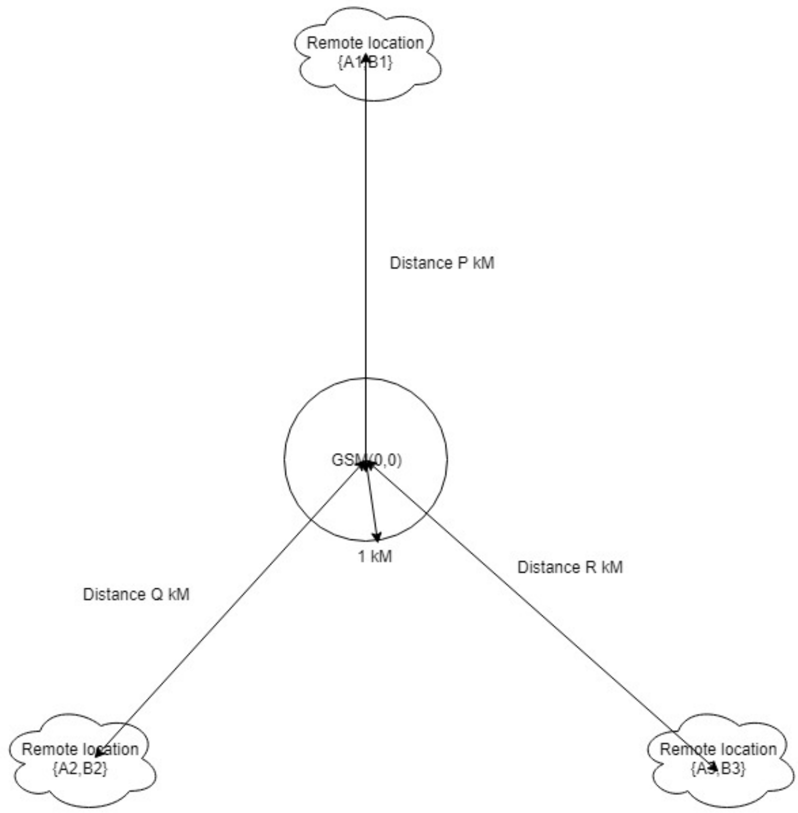

Figure 3.4: Basic schematic of data transfer from remotely located areas

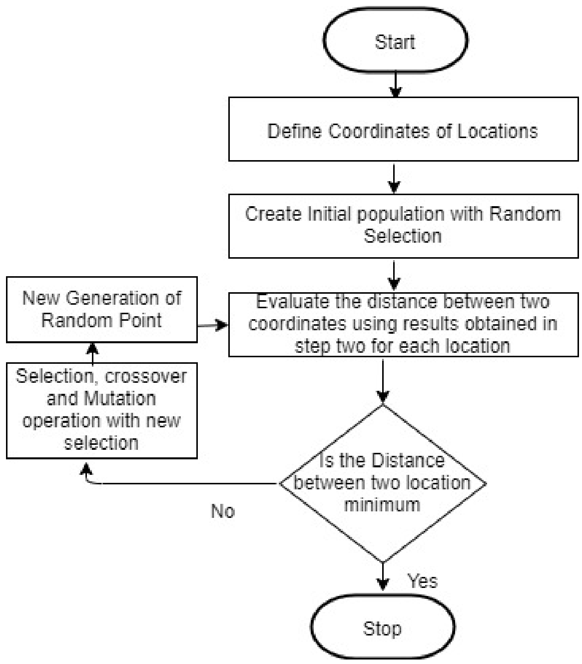

Figure 3.5: GA Flowchart

Step II Fitness definition: the objective function used in this work are:

$$F = min \sum_{j=1}^{n} \sqrt{(A_j - x)^2 + (B_j - x)^2} \tag{3.1}$$

Such that $-1 \leq x \leq 1$ and $-1 \leq y \leq 1$

$$x^2 + y^2 = r^2 \tag{3.2}$$

Where r is the range of ZigBee and n is the number of area.

Let,
Co-ordinates of Location1: (A1,B1)
Co-ordinates of Location2: (A2,B2)
Co-ordinates of Location3: (A3,B3)
Co-ordinates of GSM Network: (0,0)
Co-ordinates of centrally located ZigBee: (x, y)

Step III Population Initialization: Initially, create population of around hundreds of chromosomes by random selection. Population diversity and convergence time are the general considerations for chromosome population size selection.

Step IV Fitness Evaluation: With the help of the fitness function defined in Step II, let's calculate the fitness value for all the randomly created chromosomes in Step III

Step V Creating New Population: The existence population was replaced with newer population, which was created using the GA process Selection, crossover and followed by Mutation. With the help of Roulette wheel, the bet fit chromosomes are selected in pool for recombination. In an attempt to get better solution, two parent chromosomes will exchange genes to obtain new offspring. The revised/new chromosomes are created by setting probability at 0.8, whereas the probability for Mutation is set at 0.05 while altering Binary code.

Step VI Stopping criteria: Step IV and Step IV will be looping within till generation count reaches the set limit.

The GA generates a population size of 200 that is, it randomly selects 200 points on the circumference of the circle and then using the function cost selects out 10 minimum values. Now using these 10 values, it decides 200 more points in generation 2. Repeat this process until the number of generations are reached. That gives us the optimum point for the location of the central ZigBee (Tables 3.1 and 3.2).

Table 3.1: Input parameters

Number of areas	3
X coordinates of area 1 (A1)	1
Y coordinates of area 1 (B1)	10
X coordinates of area 2 (A2)	-4
Y coordinates of area 2 (B2)	18
X coordinates of area 3 (A3)	-7
Y coordinates of area 3 (B3)	-20

Table 3.2: Calculated coordinates using Genetic Algorithm (GA)

Optimal value of Co-ordinates to place ZigBee is	-0.5727, 1.9163

3.3.3 OPTIMAL PLACEMENT OF ZIGBEE USING PSO (WITH GEOGRAPHICAL CONSTRAINTS:

In optimal placement of ZigBee, the coordinates on the circumference of the circle, which indicate the periphery of the GSM with ZigBee are the variables and the objective is to find the minimum distances from all the '*n*' locations to that coordinate using GA has been already described in above section. Lets consider the same condition, for finding the optimized location using PSO. Now, the same case is re-optimized, considering additional constraint, as 'Geological constraint'. As the remotely located sites, may be located through very complex geographical areas, like mountains, dense forest, lakes etc, which may affect the data communication and hence location of ZigBees within these geographical area is not recommended.

If the result of optimization gives a location coordinate which is within these area(s), it may not be practically possible to install the 'communicable device' (ZigBee), and the desired purpose will not be solved. Hence, the optimization algorithm (as described above) will be modified with an additional loop. The Geo-coordinate (range) complexities will be predefined in the modified algorithm. With modified algorithm, now the result of optimization will check, if the optimized location is within the predefined constraint (range). If the result of optimization lies within the predefined constraint, then, the modified algorithm will search for next optimized point and process is looped, until we get the optimized location, which is not bounded by the defined constraint. The process is described as following:

Step I Representation: Let the chromosome *X* is denoted as $X = \{x_1, x_2\}$, where where x_1 is the longitude of the coordinate on the periphery of the GSM and x_2 is the latitude of the coordinate on the periphery of the GSM. Refer Fig. 3.4.

Step II Fitness definition: The objective function in PSO is same as defined above in GA

Step III Initialization: Initially, create population of around hundreds of chromosomes

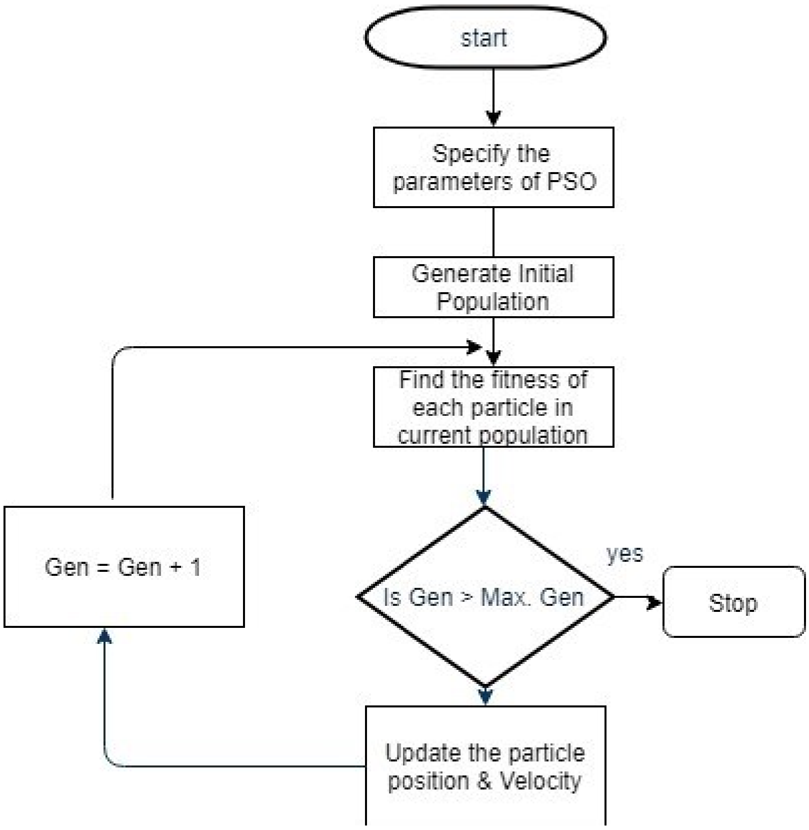

Figure 3.6: PSO flowchart

by random selection. Population diversity and convergence time are the general considerations for chromosome population size selection

Step IV Fitness evaluation: With the help of the fitness function defined in Step II, let‘s calculate the fitness value for all the randomly created chromosomes in Step III.

Step V Creating new population: The particles attempt to get best fitness, which are nominated as *'pbest'* and the particles which is best among the population of all particles is nominated as *'gbest'*. The individual best, *'pbest'* and the group‘s best *'gbest'* in the previous solution decides the velocity to move in search space, for each particle. In PSO Momentum, Cognitive and Social are the three parts, which decides the velocity update. This velocity factor obtained is used to generate the new population for next generation.

Step VI Stopping criteria: Step IV and Step IV will be looping within till generation count reaches the set limit.

Enter the co-ordinates of Geographical constraints

= $[G_{x1}, G_{y1}]$ and $[G_{x2}, G_{y2}]$

% check whether enter coordinates are inside circle or outside circle

If $-1 < G_{x1} and G_{x2} < 1, -1 < G_{y1} and G_{y2} < 1$

Then
*find the constraints coordinates on circle else
Display (‘constraints are outside the range‘)
End
*Finding the co-ordinates on circle

$$Obj = \sqrt{(G_{x1} - x_{c1})^2 + (G_{y1} - y_{c1})^2} \tag{3.3}$$

$$\sqrt{(G_{x2} - x_{c2})^2 + (G_{y2} - y_{c2})^2} = 1 - \sqrt{x_{c2}^2 + y_{c2}^2} \tag{3.4}$$

Subject to
$x_{c1}^2 + y_{c1}^2 = 1$
$x_{c2}^2 + y_{c2}^2 = 1$
Output:
Geographical co-ordinates on circles are: $[x_{c1}$ and $y_{c1}]$ and $[x_{c2}$ and $y_{c2}]$.

% Finding the optimized location of ZigBee with geographical constraint.

$$F = min \sum_{j=1}^{n} \sqrt{(A_j - x)^2 + (B_j - x)^2} \tag{3.5}$$

Such that $-1 \leq x \leq 1$ and $-1 \leq y \leq 1$

$$x^2 + y^2 = r^2 \tag{3.6}$$

Where r is the range of ZigBee and n is the number of area. $x_{c1} < x < x_{c2}$
$y_{c1} < y < y_{c2}$
Let,
Co-ordinates of Location1: (A1,B1)
Co-ordinates of Location2: (A2,B2)
Co-ordinates of Location3: (A3,B3)
Co-ordinates of GSM Network: (0,0)
Co-ordinates of centrally located ZigBee: (x,y)
The rest procedure for any technique will be followed as above.

Table 3.3: Input Parameters

Number of areas	3
coordinates of area 1 (A1 B1)	(1 10)
coordinates of area 2 (A2 B2)	(-4 18)
coordinates of area 3 (A3 B3)	(-7 -20)

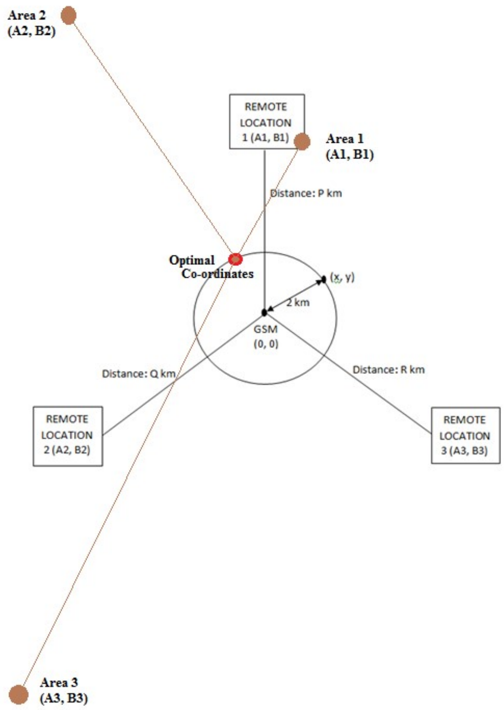

Figure 3.7: Optimal placement of ZigBee

3.3.4 COMPARISON OF RESULTS

The input values taken into consideration for the calculations are shown in Table 3.3. The calculated values of coordinates using GA and PSO are shown in Table 3.4. The graphical representation (Fig.3.7) show below displays the optimal placement of ZigBee.

Table 3.4: Calculated coordinates using Genetic Algorithm (GA) and PSO

	GA	PSO
Optimal value of Co-ordinates to place ZigBee is	(-0.5727, 1.9163)	(-0.5727, 1.9163)

3.4 CASE STUDY

The algorithm discussed as above is applied by considering center of circle at origin. However, in practice it is not so. Every point on the earth has specific GPS locations. Now when center of our location is not origin and still we want to find the GPS coordinates on periphery of the circle with 1 kM radius, then the above algorithm need to be modified, with the help of Haversine formula, so that it can be applied to any practical case study. With the help of Haversine formula, distance between two GPS Coordinates can be easily calculated. But there is no method available to find the GPS Coordinates of other point, if the GPS coordinate of one of the point and distance between them is known. In this research work, an algorithm is developed with the help of Haversine formula, through which we find the GPS coordinate of other location, if the GPS coordinates of one location and the distance between them is known. This developed algorithm is applied to a case study of four villages in state of Uttarakhand.

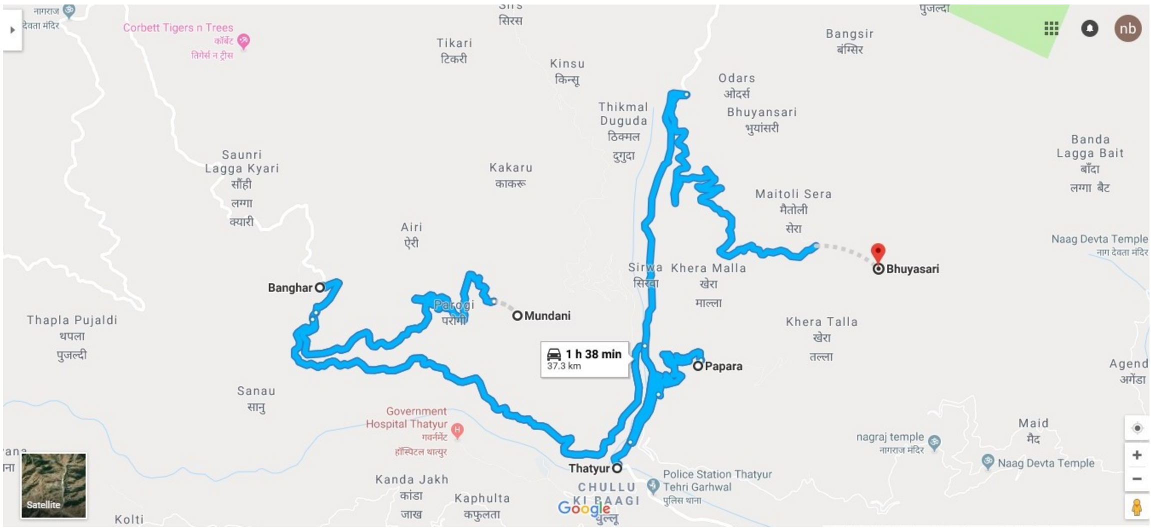

Figure 3.8: Geographical location of Villages

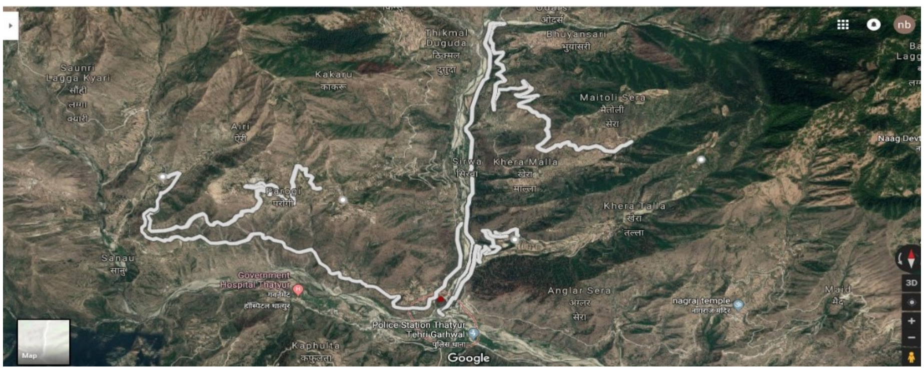

Figure 3.9: Satellite image of villages

The developed algorithm and the finding of the research work are verified through a practical case study. Four villages namely Papara, Banghar, Mundani, Bhuyasari from Pauri-Garhwal district, of state of Uttarakhand are remotely located on the hills of Uttarakhand. These villages are un-electrified. The details of these villages is as following. These villages are located surrounding to the village Thatyur in Dist. Paudi Gadhwal where electrical supply and GSM network is available. The Google Map of these four villages with Village Thatyur is as shown in Fig. 3.8 and the satellite image of same is as shown in Fig. 3.9.

3.4.1 SOCIAL STATUS OF VILLAGES

3.4.1.1 BANGHAR

Geographic GPS Coordinates: 30.511090N,78.132843W - Location 1

Banghar village is located in Dhanaulti Tehsil of Tehri Garhwal district in Uttarakhand, India. As per 2011 Census information, the village code or location code of Banghar village is 044228. Banghar is located at a distance of 44 km away from sub-district headquarter Dhanaulti and at a distance of 94 km away from district headquarter New Tehri. Banghar is approximately 40 kMs away from the nearest town Mussoorie. Banghar is the gram panchayat of Banghar village. Banghar is connected by narrow road.

The total geographical area of Banghar is 145.12 hectares. The total population of Banghar is 242 (Male: 126, Female:116). The village has around 42 houses

3.4.1.2 MUNDANI

Geographic GPS Coordinates: 30.510032N, 78.152374W - Location 2

Mundani village is located in Dhanaulti Tehsil of Tehri Garhwal district in Uttarakhand, India. As per 2011 Census information, the village code or location code of Mundani village is 044232. Mundani is located at a distance of 50 km away from sub-district headquarter Dhanaulti and at a distance of 100 km away from district headquarter New Tehri. Mundani is approximately 40 kMs away from the nearest town Mussoorie. Mundani is the gram panchayat of Mundani village. Mundani is connected by narrow road.

The total geographical area of Mundani is 372.71 hectares. The total population of Mundani is 313 (Male: 153, Female:160). The village has around 55 houses.

3.4.1.3 BHUYASARI

Geographic GPS Coordinates: 30.514342N, 78.179945W Location 3

Bhuyasari village is located in Dhanaulti Tehsil of Tehri Garhwal district in Uttarakhand, India. As per 2011 Census information, the village code or location code of Bhuyasari village is 044235. Bhuyasari is located at a distance of 43 km away from sub-district headquarter Dhanaulti and at a distance of 83km away from district headquarter New Tehri. Bhuyasari is approximately 41 kMs away from the nearest town Mussoorie. Bhuyasari is the gram panchayat of Bhuyasari village. Bhuyasari is connected by narrow road.

The total geographical area of Bhuyasari is 92.12 hectares. The total population of Bhuyasari is 319 (Male: 147, Female:172). The village has around 64 houses.

3.4.1.4 PAPARA

Geographic GPS Coordinates: 30.504605N, 78.171224W Location 4

Papara village is located in Dhanaulti Tehsil of Tehri Garhwal district in Uttarakhand, India. As per 2011 Census information, the village code or location code of Papara village is 044230. Papara is located at a distance of 41 km away from sub-district headquarter Dhanaulti and at a distance of 79 km away from district headquarter New Tehri. Papara is approximately 35 kMs away from the nearest town Mussoorie. Papara is the gram panchayat of Papara village. Papara is connected by tar road.

The total geographical area of Papara is 122.47 hectares. The total population of Papara is 378 (Male: 201, Female:177). The village has around 68 houses.

3.4.2 PROPOSED LOAD DISTRIBUTION FOR THE VILLAGE(S)

For the purpose of electrification of these four villages, it proposed to use solar and wind power plants as renewable type of power sources and DG set as back up plant in case of emergency. To estimate the total installed capacity requirement for power plants, the proposed load distribution as following:

1. Each household in the village will be provided with four LED Bulbs (4 * 7 W), two LED tube lights (2 * 18 W), two fans (2 * 30 W), two mobile charging points (2*10 W), two additional electrical points (2 * 50 W) for miscellaneous purpose. Total house hold power = 200 W (considering 50% of 2 additional electrical points)

2. Each village to be provided with 20 streetlights. (20 * 18 W = 360 W)

Table 3.5: Typical load distribution for a village

Name of Village	No. of House Holds	Power of each house	Community service	Street Light	Water Pump	Total
Banghar	42	0.2 kW	3.0 kW	0.4 kW	3.5 kW	16 kW
Mundani	55	0.2 kW	3.0 kW	0.4 kW	3.5 kW	18 kW
Bhuyasari	64	0.2 kW	3.0 kW	0.4 kW	3.5 kW	20 kW
Papara	68	0.2 kW	3.0 kW	0.4 kW	3.5 kW	20.5 kW

Table 3.6: Typical energy consumption for a day.

Name of Village	No. of House Holds	Power of each house*LF* Operating hours	Community service*LF * Operating Hours	Street Light *LF* Operating Hours	Water Pump*LF * Operating hours	Total kWH
Banghar	42	0.2 kW*1*6	3.0 kW*0.67*4	0.4 kW*1*12	3.5 kW*1*4	77 kWH
Mundani	55	0.2 kW*1*6	3.0 kW*0.67*4	0.4 kW*1*12	3.5 kW*1*4	93 kWH
Bhuyasari	64	0.2 kW*1*6	3.0 kW*0.67*4	0.4 kW*1*12	3.5 kW*1*4	106 kWH
Papara	68	0.2 kW*1*6	3.0 kW*0.67*4	0.4 kW*1*12	3.5 kW*1*4	112 kW

3. Each Village will be provided with a water pump of 5 HP (3.5 kW)

4. Some common area of the village will be marked for School, Infirmary, shop, common utility area. This common area will be provided with 5 LED Tube Lights (5*18 W), four fans (4 * 30 W), one TV Set with projector (1 * 100 W), one AC (1 * 1.5 kW), one heating point (1 * 1 kW), five mobile charging points (50 W), five additional electrical points (5 * 100 W). Total approx = 3 kW

5. The total installed capacity of power plants for each village is as tabulated in Table 3.5.

6. Typical energy consumption and maximum demand (Table 3.6):
   (a) The total connected house load is reasonably low, and hence LF for household is considered as 1 with 6 operating hours.
   (b) The load factor for community service is considered as 0.66, with assumption that refrigerator will be 'ON' all the time and averaged operating hours are considered as 4 hours.
   (c) The Water pumps will operate only during daytime with of operating hours.
   (d) Street lights will 'ON' for 12 hours a day

The demonstrative diagram for power distribution for a village is as shown in Fig. 3.10.

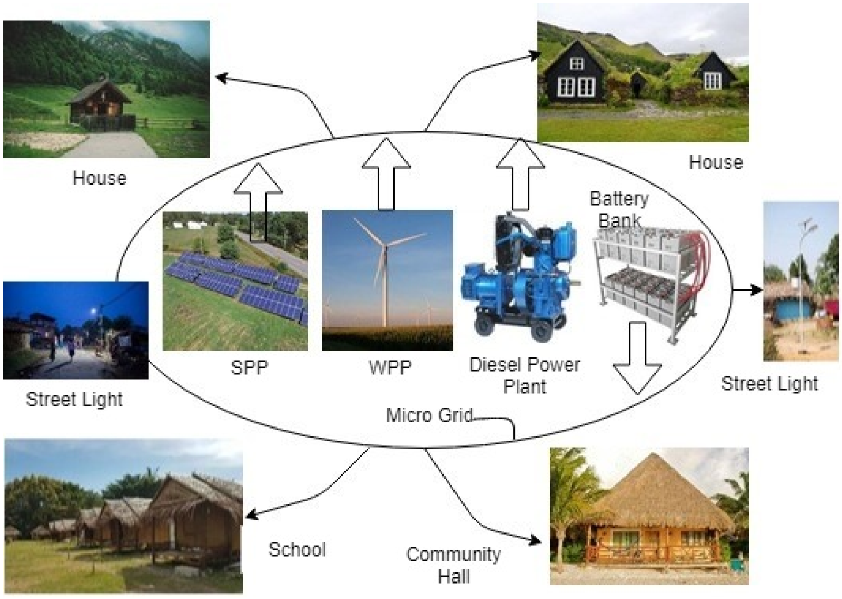

Figure 3.10: Representative load flow diagram

3.4.3 AVAILABLE RESOURCES AND SIZE OF POWER PLANTS

As proposed to install Solar power plant and Wind Power plants, it is important to understand the availability of resources that is Solar radiation and Wind speed available at each location and almost similar geographical location and as per available data, the Solar radiation and wind speed is same around all villages. The averaged Solar radiation and wind speed is as described.

3.4.3.1 SOLAR RADIATION DATA

The available solar radiation on (all) the locations is represented as shown in Figs. 3.11 and 3.12. As all the location are in very close vicinity the available solar radiation at all the locations are same. From the Fig. 3.11 it can be concluded that, the solar power plants can generate in the range of 3 to 6 kW/m^2 and hence, based on the requirement suitable size of power plants are selected for the each location.

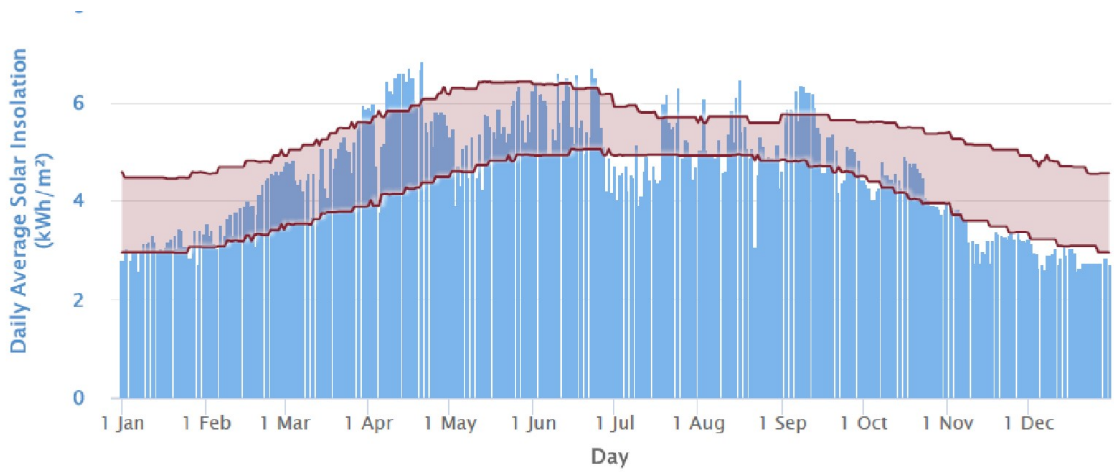

Figure 3.11: Typical solar radiation over a year

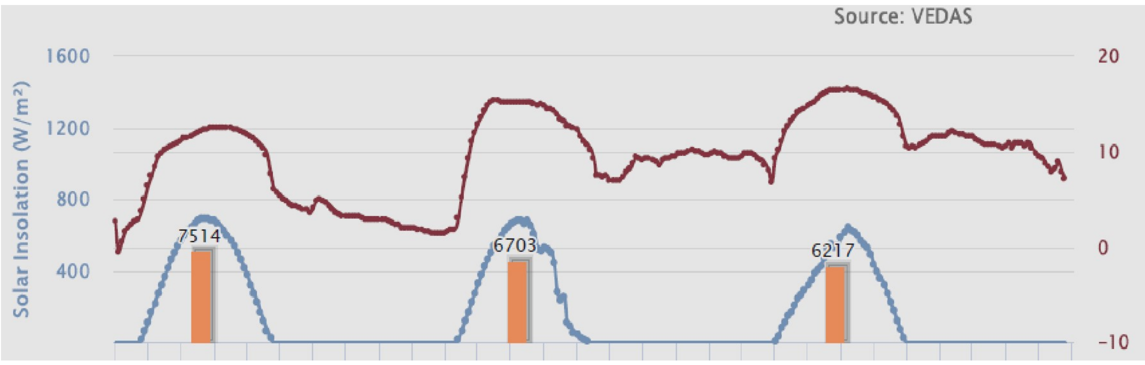

Figure 3.12: Typical solar radiation over 3 days

3.4.3.2 WIND SPEED DATA

Based on the NIWE the wind potential at the specified site location is limited. The available wind speed data is as per Table 3.7. It can be seen that, typically maximum wind speed is hardly around 6-7 kms and thus the wind energy potential is limited.

3.4.3.3 POWER PLANT SIZES

From the load distribution table and with available solar and wind potential, the typical suggested power plant sizes are as tabulated in Table 3.8. It can be seen that the total energy demand for a typical day can go up to 110 units and MD is around 15 kWH.

Table 3.7: Typical wind speed at the specified locations, selected for the case study.

50mWS	50mSD	30mWS	30mSD	10mWS	10mSD	50mDIR	30mDIR	Temp
3.7	0.67	4.16	0.63	4.02	0.87	205.18	196.51	4.76
3.93	0.56	4.38	0.62	4.15	0.89	204.49	195.78	4.68
3.87	0.62	4.15	0.75	3.71	1.12	206	195.88	4.55
3.33	0.46	3.56	0.5	3.68	0.69	210.24	196.18	4.28
0.3	0	0.46	0.27	0.29	0	197.31	183.11	2.46
0.3	0	0.26	0	0.29	0	197.32	183.11	2.3
0.3	0	0.26	0	0.29	0	197.32	183.11	2.36
0.48	0.3	0.72	0.45	0.32	0.12	197.34	183.12	2.56
0.3	0	0.34	0.2	0.29	0	197.35	183.12	2.52
0.3	0	0.46	0.27	0.29	0	197.31	183.11	2.46
4.28	0.38	3.92	0.43	3.14	0.54	1.43	2.68	3.03
4.39	0.37	3.82	0.46	3.22	0.48	0.51	2.26	2.97
4.26	0.42	3.89	0.48	3.24	0.53	359.11	357.77	3.3
4.51	0.44	4.12	0.45	3.29	0.51	357.24	356.92	3.29
5.9	1.04	4.71	1.15	3.87	1.19	325.47	326.23	8.08
5.67	1.14	4.76	1.08	3.76	1.26	326.99	328.92	7.98
5.83	1.51	5.06	1.49	4.06	1.48	327.6	327.26	7.85
6.24	1.48	5.8	1.48	4.99	1.49	336.11	337.84	7.89

Table 3.8: Typical rating (sizes) of power plants.

Type of power plant	Size of power plant	Area required, m^2	Remark
Solar power plant	30 kWp	325	Main power plant
Wind power plant	5 kW	5	Main power plant
Battery bank	100 kWh	10	Energy storage
DG Set	20 kW	10	Back up

3.4.4 DATA COMMUNICATION FROM VILLAGES:

The geographical locational representation of these four villages and the central village Thatyur is as shown in the following diagram Fig. 3.13. It is required to communicate the data from the 'remote power systems' of all these four villages to Thatyur through Local Area Network (LAN). The word 'data' refers to the various technical parameters (like voltage, current, temperature etc.) related to remotely located power systems, which can help to estimate the health of remotely located power system(s). In the research work, ZigBee based communication network is preferred as Local Area Network to communicate the data from 'remotely located power system(s)' to nearby GSM network (Thatyur). ZigBee based communication networks can effectively communicate at a distance of one kilometer, hence one km is considered as 'communicable distance' for the purpose of research work and optimization. In the proposed case study, GSM network is available in Thatyur, thus it is required to communicate the information from all four locations to the nearest GSM Location that is at Thatyur. All four villages are at located at a distance

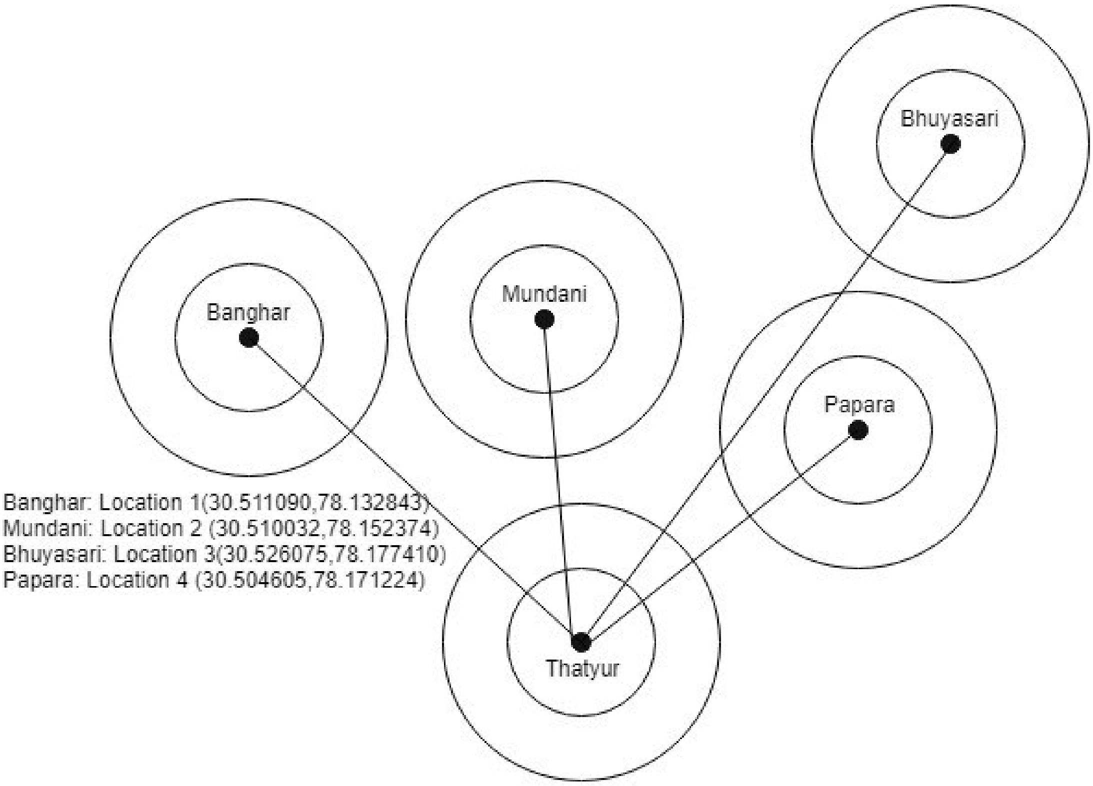

Figure 3.13: Graphical representation of villages

of more than one km from Thatyur and are located in different directions. To ensure a proper communication from all villages to Thatyur, chain(s) of ZigBee network need to be created.

The communication from all four villages to the central location village Thatyur needs to effective and with minimum disturbance. The communication can be effective and with minimum disturbance, if the 'two communicating nodes' are within vicinity. The word 'vicinity' defines 'all expected characteristics' for two nodes to communicate. The expected characteristics, includes, mainly distance between two nodes, mode of communication, type of communication, etc. The communicating nodes should be kept within the communicable distance and for ZigBee communication network 'communicable distance' is presumed as one kM. Now, it is required to communicate from 'power systems' of all villages to central locations Thatyur.

3.4.5 ZigBee NETWORK WITHOUT OPTIMIZATION

For the considered case study, let's first understand the structure of ZigBee Network, without any optimization. As there is no optimization, it is applied that, for every 1 kM distance a pair of ZigBee is installed all over the straight line distance between the Source

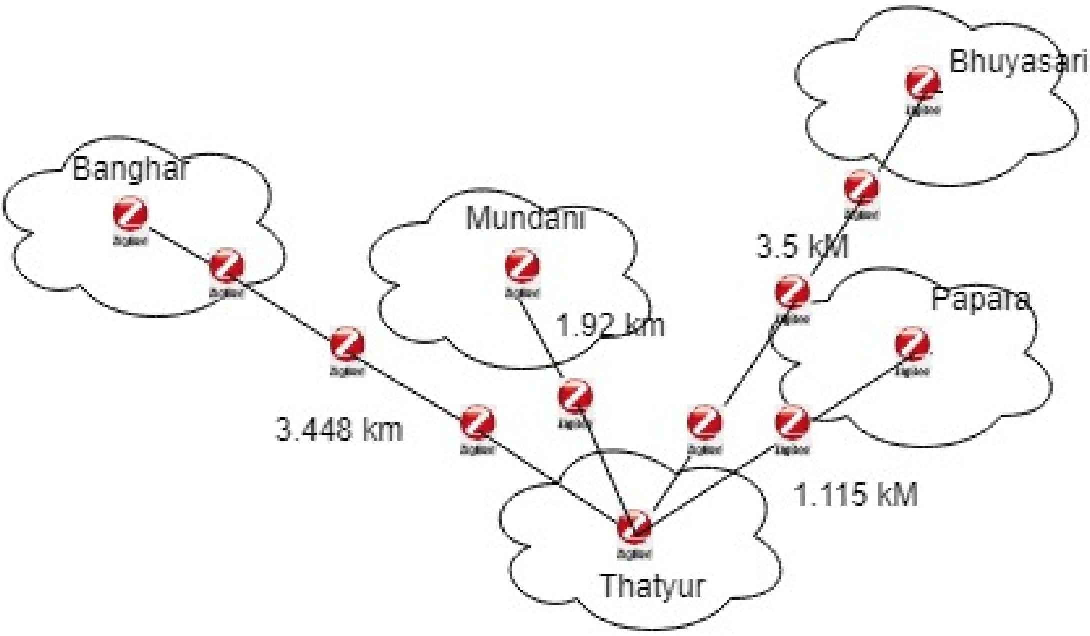

Figure 3.14: ZigBee structure without pptimization

Village and Destination Village (Thatyur in this case).Table 3.9 gives the straight-line distance between the each village to Thatyur.

Table 3.9: Straight line distance between Villages.

Source village	GPS coordinates	Destination location	GPS coordinates	Straight line distance (kM)	No. of (intermediate) ZigBee required
Banghar	30.51109, 78.13284	Thatyur	30.4964, 78.16454	3.448	3
Mundani	30.51003, 78.15237	Thatyur	30.4964, 78.16454	1.92	1
Bhuyasari	30.52608, 78.17741	Thatyur	30.4964, 78.16454	3.5	3
Papara	30.50461, 78.17122	Thatyur	30.4964, 78.16454	1.115	1

From the Table3.9 it can be seen that, without any optimization for the said case study, we would have required around Eight intermediate ZigBee, plus Five ZigBee for the center of each village. In addition, finding the exact GPS Coordinates for these ZigBees is also a challenging task.

3.4.6 THE PROCESS OF OPTIMIZATION

In the new algorithm developed in the research work, the process of Optimization is primarily divided in 'three' major steps, with each major steps has many sub steps and loops. described as follows:

STEP I: Identify all the GPS Coordinates (Latitude and Longitude) on the periphery of a circle of radius one kilometer from the center of the first village. (Banghar in this case). Repeat the same step for all other villages. (Mundani, Bhuyasari, Papara, Thatyur)

STEP II: Identify the GPS Coordinates on these circles (for all villages) with most nearest GPS Coordinate (on the circle as identified in step II) with neighborhood village's circles. These GPS Coordinates will be our 'proposed' GPS Coordinates for the purpose of installation of ZigBee.

STEP III: From these 'proposed GPS Coordinates'; final GPS Coordinates are selected with the help of optimization.

3.4.7 STEP I:FINDING GPS COORDINATES AROUND A DEFINED GPS COORDINATE

The first step is to identify the set of GPS Coordinates on the perimeter of circle of one kilometer around the locations. Develop a novel algorithm to identify the GPS Coordinates, using Haversine formulae. The algorithm uses Haversine formula to calculate the distance between two GPS Coordinates on the Earth. Haversine formula is applied to find the 'aerial distance' also called as 'crow fly distance' between two GPS Coordinates.

ALGORITHM:

1. Let the GPS Coordinates of First location is Latt1, Long1 (Centre of circle). GPS Coordinates of village Banghar in this case.
2. Consider a circle of 1 kM around this center. Radius of 1 kM is considered, with justification that, ZigBee can communicate at a distance of 1 kM. Thus if first ZigBee is at center of location 1, then the location of second ZigBee should be on the circumference of circle (with radius of 1 km) having GPS Coordinates of center at Latt1, Long1.
3. We note that, GPS coordinates of the different points of the circle will be different.
4. Now, it is required to find these GPS Coordinates over the perimeter of circle. Let the GPS Coordinate of these points are from Latt11, Long11....Latt1n,Long1n
5. Use Haversine formula to identify the GPS Coordinates of these points on the periphery of circle.

6. The Haversine formula is :

$$a = sin^2(\Delta Latt/2) + cos(Latt1).cos(Latt2) * sin^2(\Delta Long/2) \tag{3.7}$$

$$c = 2 \times asin(min(1, \sqrt{a})) \tag{3.8}$$

$$d = R * c \tag{3.9}$$

   Where all angles are in radians and R = 6371000 meters (radius of the Earth). and $\Delta Latt = (Latt2 - Latt1)$ and $\Delta Long = (Long2 - Long1)$ are difference in Latitude and Longitude of the two points between which distance is to be calculated.

7. As GPS Coordinates of second point is not available, use optimization to locate the GPS Coordinates of second point.

8. Start the first iteration by assigning $\Delta Latt = -0.1$ and $\Delta Long = -0.1$. With the help of Haversine formula, distance between two points Latt1, Long1 and Latt1+ $\Delta Latt$, Long1+ $\Delta Long$ is calculated.

   If this distance is equals to 1000 m (between 999.9 m to 1000.1 m), then we can say that GPS Coordinates of second point (Latt11,Long11) are Latt 11=Latt1+ $\Delta Latt$ and Long11= Long1+ $\Delta Long$.

9. However, if the result of first iteration is not as desired (that is, distance is not between 999.9 m to 1000.1 m), then value of $\Delta Long$ is further incremented by 0.00001 to -0.09999 and calculation is repeated. Repeat the loop is until distance is equal to 1000 m (between 999.9 m to 1000.1 m).

10. When distance is equal to 1000 m (between 999.9 m to 1000.1 m) then, the GPS coordinate of first point on the circle at a radius of 1 km from center (Latt11,Long11) can be assigned as Latt 11=Latt1+ $\Delta Latt$ and Long11= Long1+ $\Delta Long$.

11. To find the GPS Coordinate of next point on the circle, now the value of $\Delta Latt$ is incremented by 0.00001 and the value of $\Delta Long$ is further incremented from -0.1 to 0.1, with an increment of 0.00001 until the distance is equal to 1000 m (between 999.9 m to 1000.1 m). Once the distance is 1000 m (between 999.9 m to 1000.1 m), then the GPS Coordinate of second location on the perimeter of circle of radius of 1 km from center (Latt1,Long1) can be assigned as Latt 12=Latt1+ $\Delta Latt$ and Long12= Long1+ $\Delta Long$.

12. The optimization will continued until all approximate points on the perimeter of circle and their GPS Coordinates are calculated and assigned from Latt11 to Latt1xxx and Long11 to Long1xxx and stored in an array.

The flow chart for the algorithm is as shown in Fig. 3.15.

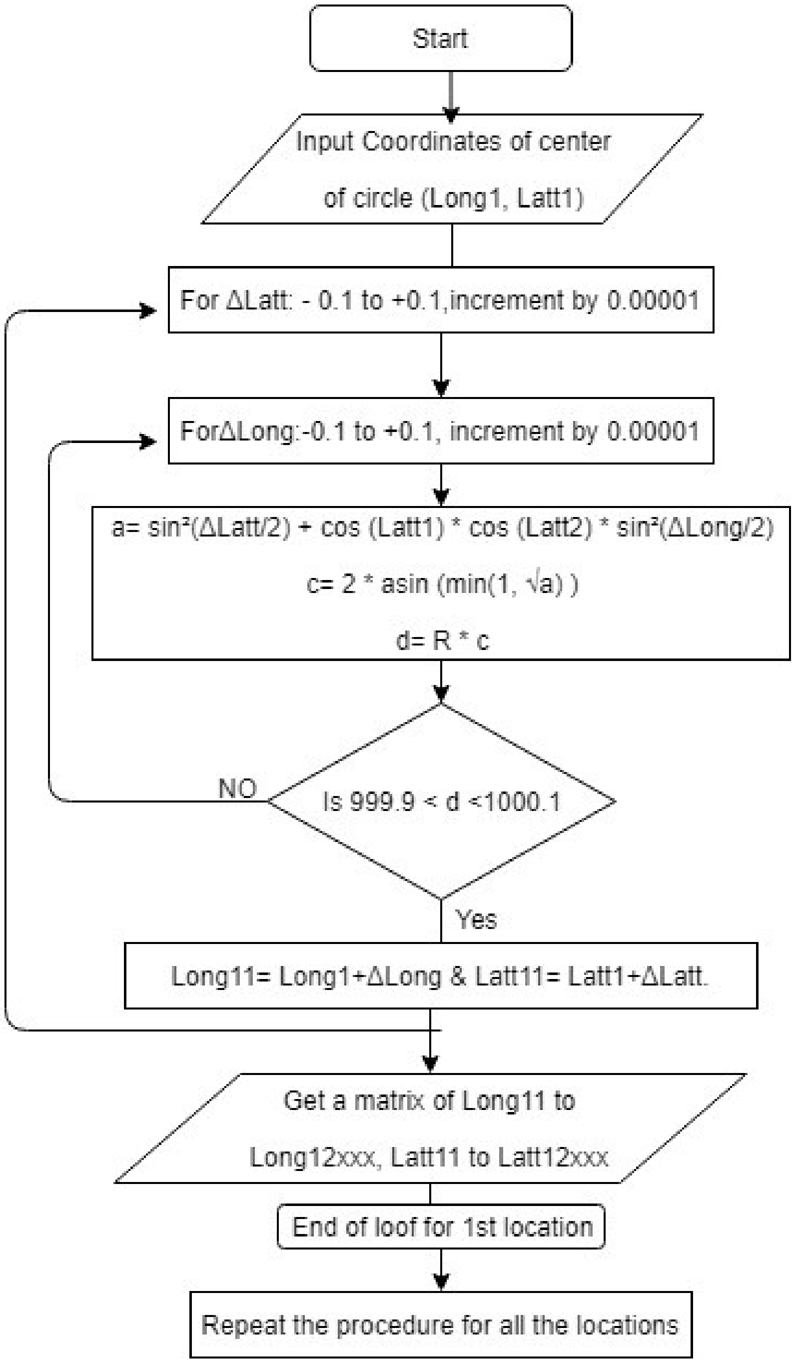

Figure 3.15: Flow chart for Step I

3.4.7.1 RESULT OF STEP I

The results of the optimization of Step I are tabulated as in Table 3.10. The plot of result of GPS Coordinates in Table 3.10 on Google map is as shown in Fig. 3.16.

The map shows five circles around all five villages. From the Fig. 3.16 it is clear the the

Table 3.10: GPS Coordinates of points on the Circles

Banghar		Mundani		Bhuyasari		Papara		Thatyur	
Latitude	Longitude	Latitude	Longitude	Latitude	Longitude	Latitude	Longitude	Latitude	Longitude
30.51071	78.12241	30.50965	78.14194	30.52594	78.16697	30.50424	78.16079	30.49605	78.15411
30.51072	78.12241	30.50966	78.14194	30.52595	78.16697	30.50425	78.16079	30.49606	78.15411
30.51073	78.12241	30.50967	78.14194	30.52596	78.16697	30.50426	78.16079	30.49607	78.15411
30.51074	78.12241	30.50968	78.14194	30.52597	78.16697	30.50427	78.16079	30.49608	78.15411
30.51144	78.12241	30.51038	78.14194	30.52598	78.16697	30.50428	78.16079	30.49609	78.15411
30.51145	78.12241	30.51039	78.14194	30.52599	78.16697	30.50494	78.16079	30.49671	78.15411
30.51146	78.12241	30.5104	78.14194	30.526	78.16697	30.50495	78.16079	30.49672	78.15411
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
30.51072	78.14327	30.50966	78.1628	30.52616	78.18785	30.50427	78.18165	30.49608	78.17497
30.51073	78.14327	30.50967	78.1628	30.52617	78.18785	30.50428	78.18165	30.49609	78.17497
30.51074	78.14327	30.50968	78.1628	30.52618	78.18785	30.50494	78.18165	30.49671	78.17497
30.51144	78.14327	30.51038	78.1628	30.52619	78.18785	30.50495	78.18165	30.49672	78.17497
30.51145	78.14327	30.51039	78.1628	30.5262	78.18785	30.50496	78.18165	30.49673	78.17497
30.51146	78.14327	30.5104	78.1628	30.52621	78.18785	30.50497	78.18165	30.49674	78.17497
30.51147	78.14327	30.51041	78.1628	30.52622	78.18785	30.50498	78.18165	30.49675	78.17497
Total 1124 GPS Coordinates		Total 1122 GPS Coordinates		Total 1162 GPS Coordinates		Total 1146 GPS Coordinates		Total 1106 GPS Coordinates	
Total 5660 probable GPS Coordinates for installation of ZigBees									

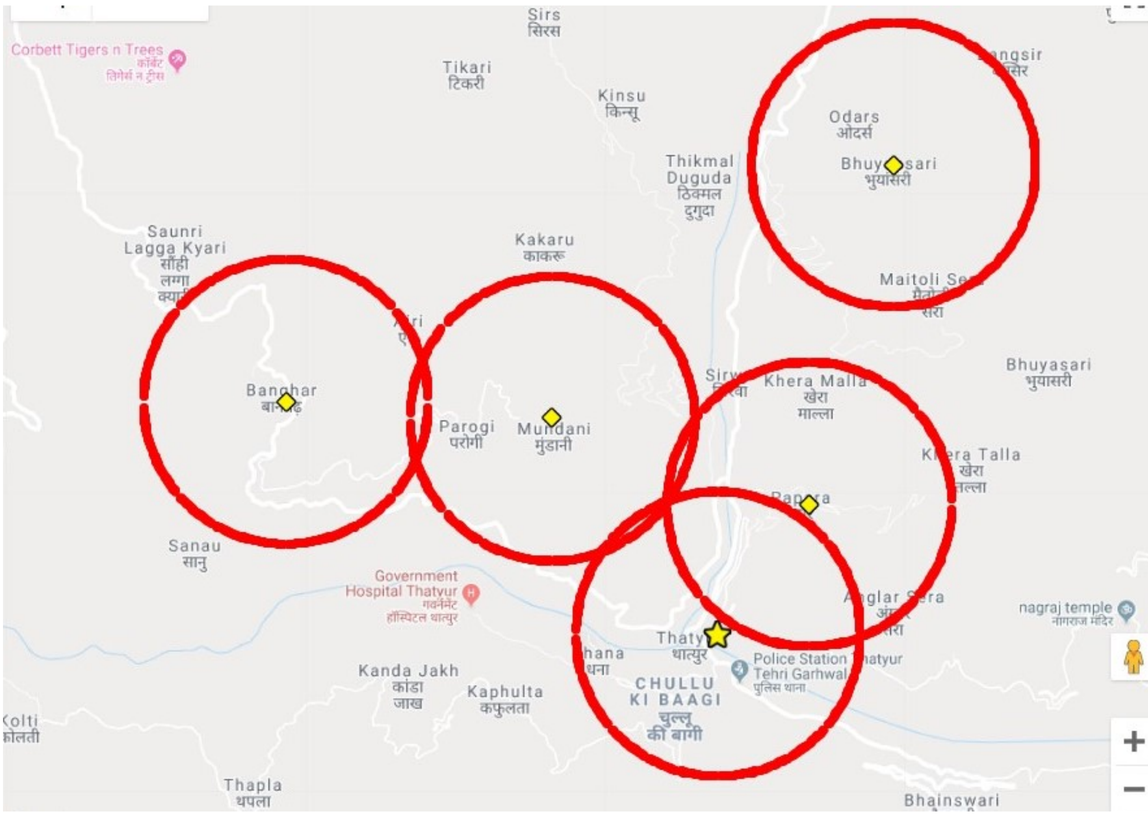

Figure 3.16: Plot of 5660 GPS coordinates on Google map

new developed algorithm has given the GPS Coordinates of around thousands of points around the villages at a distance of 1kM with an accuracy of 1 cm. There are around 1100+

points (3.10)around each village. With 1 kM radius, the perimeter of circle is around 6.28 km. With around 1100 points spread over 6.28 kMs, we can say the approximate distance between two nearest point on the circle is 6 Meters. The accuracy (less than 1 cm) and distance between the two points (less than 6 m) can be easily modified, by changing the increment count. However, lower the increament count, the computational time will increase substantially. 6 m distance between two probable GPS Coordinate on the circle is good enough consideration for further part of algorithm.
The next step of algorithm is to reduce the 'probable' GPS locations from 5560 (Table 3.10).

3.4.8 STEP II: FINDING TWO MOST NEIGHBORING GPS CO-ORDINATES ON THE CIRCLES.

After finding the GPS coordinates of locations (5660 in total), within the vicinity of 1 kM, the next step is to find the set of GPS Coordinates (from these 5660 GPS coordinates) which are nearest to all other locations, to decide the estimate the final GPS coordinates. The logic used is, using Haversine formula find the distance between all the obtained 5660 GPS Coordinates (in Step 1). Assign the GPS coordinates, which gives the minimum distance as 'closest GPS Coordinates' for the two circles.

1. The results of Step I are stored in form of array.
2. Array will consist of 10 columns. For each GPS Coordinate, two columns consist of Latitude and Longitude.
3. Calculate the distance between first GPS Coordinate of the first location (say Latt11, Long11) and the first GPS Coordinate of Second location (Say Latt21, Long21) and store as say 'Dm1211'.
4. In second calculation, now the distance between first GPS Coordinate of the first location (say Latt11, Long11) and the second GPS Coordinate of Second location (Say Latt22, Long22) will calculated and stored as say 'Dm1212'. Calculate all distances for the first GPS Coordinate of circle of Location 1 to all GPS Coordinates of the circle of Location 2. All these distances will be stored in an array.
5. In next iteration, now the distance between second GPS Coordinate of the first location (say Latt12, Long12) and the first GPS Coordinate of Second location (Say Latt21, Long21) will calculated and stored as say 'Dm1221'. Calculate all distances for the second GPS Coordinate of circle of Location 1 to all GPS Coordinates of the circle of Location 2. All these distances will be stored in an array.
6. In this way, identify the distances between all GPS Coordinates of circle of Location 1 verses all the GPS Coordinates of circle of Location 2 and store in an array.

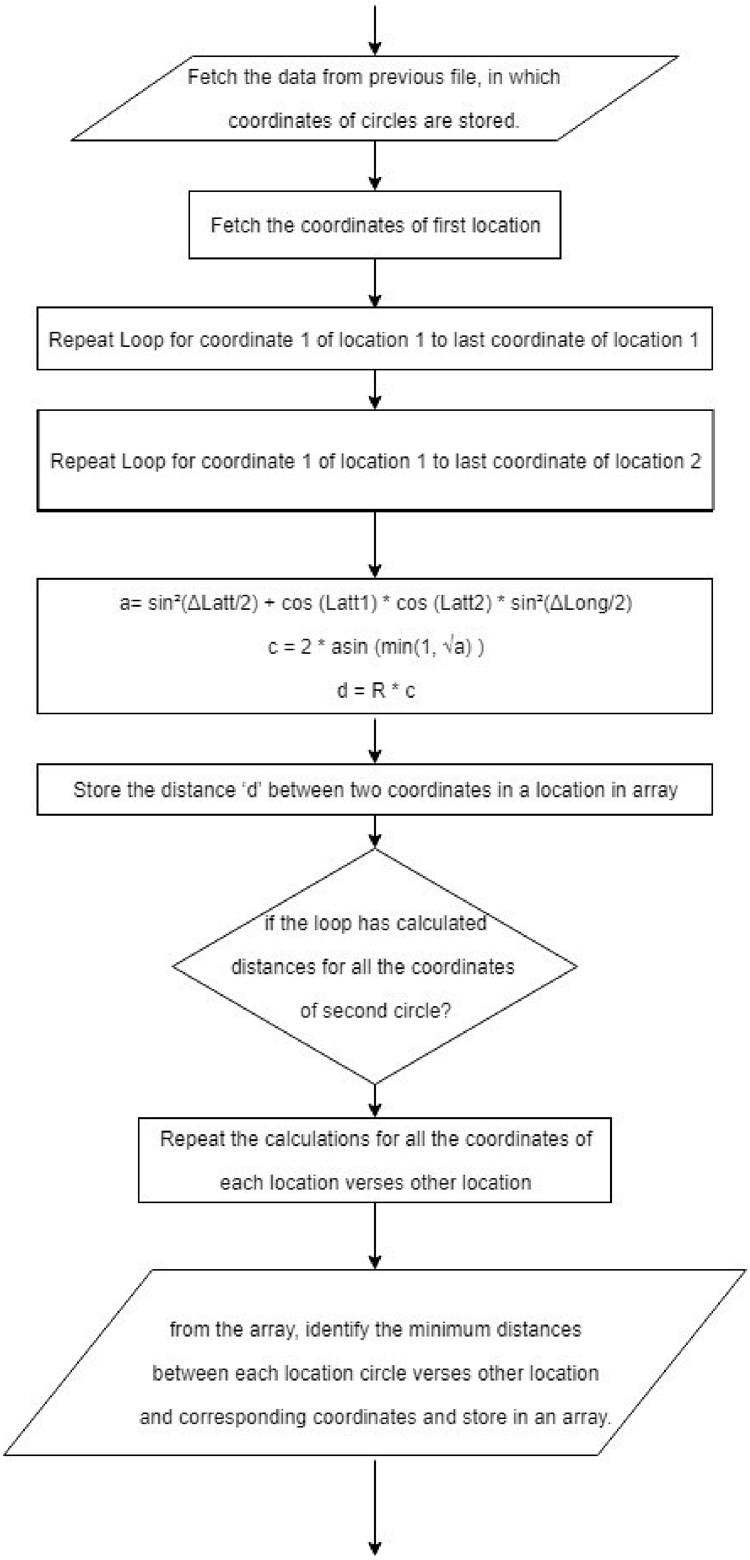

Figure 3.17: Flowchart for Step II

7. Array will consist of 10 columns. For each GPS Coordinate, two columns consist of Latitude and Longitude.

8. Calculate the distance between first GPS Coordinate of the first location (say Long11, Long11) and the first GPS Coordinate of Third location (Say Long31, Long31) and store as say 'Dm1311'.

9. In second calculation, now the distance between first GPS Coordinate of the first location (say Latt11, Long11) and the second GPS Coordinate of Third location (Say Latt32, Long32) will calculated and stored as say 'Dm1312'. Calculate all distances for the first GPS Coordinate of circle of Location 1 to all GPS Coordinates of the circle of Location 3. All these distances will be stored in an array.

10. In next iteration, now the distance between second GPS Coordinate of the first location (say Latt12, Long12) and the first GPS Coordinate of third location (Say Latt31, Long31) will calculated and stored as say 'Dm1321'. Calculate all distances for the second GPS Coordinate of circle of Location 1 to all GPS Coordinates of the circle of Location 3. All these distances will be stored in an array.

11. In this way, identify the distances between all GPS Coordinates of circle of Location 1 verses all the GPS Coordinates of circle of Location 3 and store in an array.

12. Repeat the above procedure to calculate the distance between the all GPS Coordinates of circles of all the locations and all the distances will be stored in arrays. In this case, 10 arrays will be generated as there are 5 locations and there are 10 various combinations, as Location 1-2, Location 1-4, Location, 2-5, Location 4-5 etc.

13. With the help of minimum function, identify the minimum distances between any locations, (in this case ten combinations) and store the corresponding GPS Coordinates in form of array.

14. For every combination (of locations), identify two lowest distances and their corresponding locations.

3.4.8.1 RESULT OF STEP II

The codes written for Step II of algorithm are successfully compiled. The post compilation results of Step II are as shown in Table 3.11. The plot of all GPS Coordinates of Step I and Step II are as shown in Fig. 3.18.

With reference to Table 3.11, it can be seen that, the algorithm has selected 40 GPS Coordinates from 5560 GPS Coordinates. Algorithm has selected two GPS Coordinates for each combination of villages. Since there are 20 possible combinations between 5 villages, there are 40 GPS Coordinates. Thus, With the help of New algorithm the probable 5560 GPS Coordinates are reduced to just '40' GPS Coordinates. However, STEP III provides the further optimization to minimize the number of GPS locations.

Table 3.11: Result of Step II

Sr.No.	Location	Latitude	Longitude	Latitude	Longitude	Distance in m
1	1/2	30.5137	78.14283	30.51368	78.14283	0.426022
2	1/2	30.50744	78.14238	30.50742	78.14238	0.426037
3	1/3	30.51147	78.14327	30.52594	78.16697	2655.589
4	1/3	30.51146	78.14327	30.52594	78.16697	2655.617
5	1/4	30.51071	78.14327	30.50498	78.16079	1952.641
6	1/4	30.51071	78.14327	30.50497	78.16079	1952.656
7	1/5	30.51071	78.14327	30.49675	78.15411	1246.47
8	1/5	30.51071	78.14327	30.49693	78.15412	1246.501
9	2/3	30.51106	78.16274	30.52511	78.16703	574.1916
10	2/3	30.51106	78.16274	30.52504	78.16704	574.2273
11	2/4	30.50475	78.16082	30.50494	78.16079	5.343896
12	2/4	30.50475	78.16082	30.50495	78.16079	5.523958
13	2/5	30.50163	78.1561	30.50169	78.1561	1.418074
14	2/5	30.50492	78.16096	30.50485	78.16097	1.751752
15	3/4	30.51745	78.17447	30.51317	78.17442	97.66438
16	3/4	30.51748	78.17436	30.5132	78.17431	97.66528
17	3/5	30.51885	78.1712	30.50361	78.17078	350.3707
18	3/5	30.51885	78.1712	30.50359	78.17081	350.3936
19	4/5	30.49621	78.17495	30.49609	78.17497	3.148507
20	4/5	30.49622	78.17498	30.49609	78.17497	3.225984

3.4.9 STEP III: FINDING THE FINAL GPS COORDINATE(S) FOR PLACEMENT OF ZIGBEE'S:

In Step I, we have identified the locations of GPS Coordinates on the periphery of the circles of 1 km radius around the village centers. As mentioned, 1 km radius is considered as ZigBee can communicate over 1 km. From the results (Table 3.10), it can be concluded that, if the GPS Coordinate of ZigBee is at the center of say village 1(Banghar), then the next probable GPS Coordinate of ZigBee can be any one of 1124 GPS Coordinates (column 1 and column 2 of Table 3.10). Thus, Step I gives a set of probable GPS Coordinates for installation of second (next) ZigBee, for the village 1. Likewise, we got around 5560 points (min. of 1106 GPS Coordinates for location 5 to max. of 1156 GPS Coordinates for location 3) as shown in Table 3.10 for all 5 locations combined together.
In Step II, with the help of optimization, the set of 5560 GPS Coordinates are reduced to 40 locations (GPS Coordinates) as shown in Table 3.11.
In step III with further optimization, the final minimum number of GPS Coordinates are identified.

1. It is required to communicate data from each location's center to final destination. In the case study village 1 to 4 (Village 1: Banghar, Village 2: Mundani, Village 3: Bhuyasari, Village 4: Papara) are central locations and Thatyur is final destination. The condition to fulfill for data communication from village(s) to Thatyur is that, there must a one ZigBee at each center (village) and then a chain of ZigBee(s) at a distance of 1 km each, till the destination Thatyur. The indicative representation is as shown in Fig. 3.19.

2. The result of Step II are stored in form of arrays, where in the first column gives

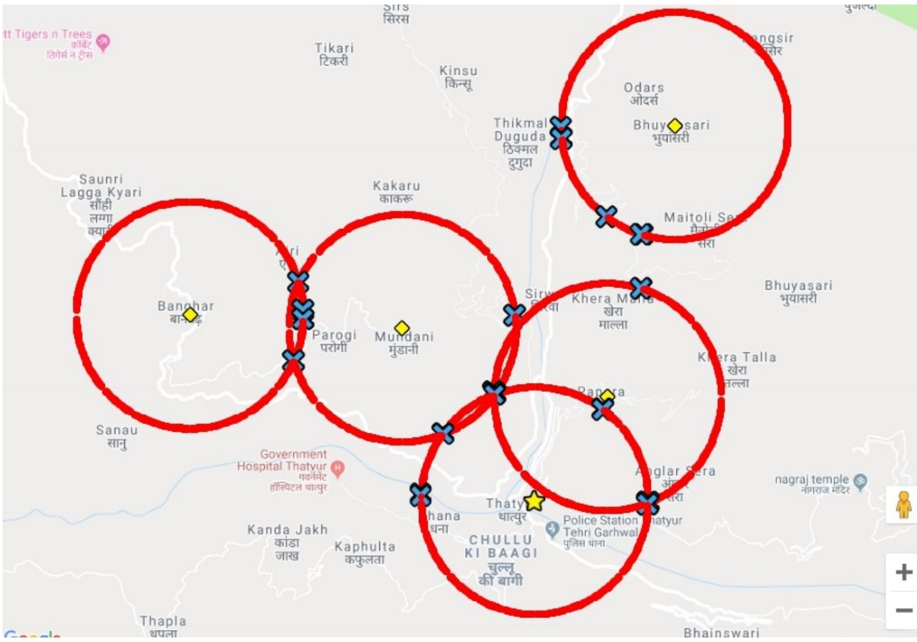

Figure 3.18: Result of Step I and Step II plotted on Google Map

the 20 combinations of all five locations (like 1-2,3-5, 4-5 etc).2^{nd} to 5^{th} column gives the GPS Coordinates correspond to minimum distance between the said two locations and last 6^{th} column gives the minimum distance correspond to location pair in column 1.

3. **First elimination:** In step 1, for a circle of 1 kM radius, we have got around 1100+ points. It can be concluded that for a perimeter of 6.28 km, a set of 1100+ points are available. Thus the approximate distance between the two successive points on the circle is 6 m. So for the purpose of simplicity in optimization, all the pairs of GPS Coordinates, where minimum distance is less than 6 m (in column 6) are considered as a one location only. Thus in Table 3.11, for Sr. No. 1,2,11,12,13,14,19,20 each set of two location will be considered as (any one of GPS Coordinate) as probable location. So 40 sets of GPS Coordinate will be further reduced to 32 GPS Coordinates (as 8 sets of GPS Coordinates will get eliminated). The revised table of GPS Coordinates is as in Table 3.12.

4. **Second elimination:** In next optimization process (second elimination), if a circle (of say location 1) is intersecting with any other circle (may be one of circle or more than one circles) then, it can be again concluded that, as the circle (of location 1) is intersecting with one of other circle (of other location), then distance between these two corresponding circles is near minimum. Thus for that location (location 1) all other locations (whose circles are not intersecting) are of no practical importance as they cannot be 'probable locations'. Thus the revised table of probable GPS Coordinates is as in Table 3.13. It can be observed that 32 probable GPS Coordinates are reduced to 20 probable GPS Coordinates.

5. **Third elimination:** In next optimization step (third elimination), if circle of any particular location is not intersecting with any other circle (of other location), then it

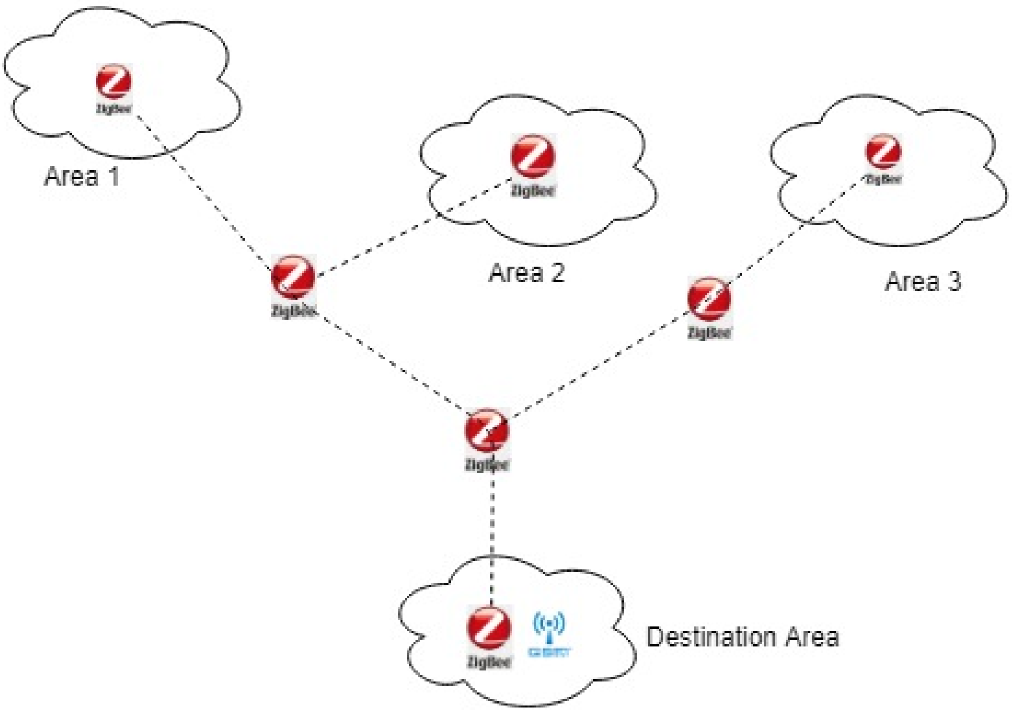

Figure 3.19: The indicative representation for locations of ZigBee

Table 3.12: Revised GPS coordinate after first elimination process

Sr.No.	Location	Latitude	Longitude	Latitude	Longitude	Distance in m
1	1-2	30.5137	78.14283	30.51368	78.14283	0.426022
2	1-2	30.50744	78.14238	30.50742	78.14238	0.426037
3	1-3	30.51147	78.14327	30.52594	78.16697	2655.589
4	1-3	30.51146	78.14327	30.52594	78.16697	2655.617
5	1-4	30.51071	78.14327	30.50498	78.16079	1952.641
6	1-4	30.51071	78.14327	30.50497	78.16079	1952.656
7	1-5	30.51071	78.14327	30.49675	78.15411	1246.47
8	1-5	30.51071	78.14327	30.49693	78.15412	1246.501
9	2-3	30.51106	78.16274	30.52511	78.16703	574.1916
10	2-3	30.51106	78.16274	30.52504	78.16704	574.2273
11	2-4	30.50475	78.16082	30.50494	78.16079	5.343896
12	2-4	30.50475	78.16082	30.50495	78.16079	5.523958
13	2-5	30.50163	78.1561	30.50169	78.1561	1.418074
14	2-5	30.50492	78.16096	30.50485	78.16097	1.751752
15	3-4	30.51745	78.17447	30.51317	78.17442	97.66438
16	3-4	30.51748	78.17436	30.5132	78.17431	97.66528
17	3-5	30.51885	78.1712	30.50361	78.17078	350.3707
18	3-5	30.51885	78.1712	30.50359	78.17081	350.3936
19	4-5	30.49621	78.17495	30.49609	78.17497	3.148507
20	4-5	30.49622	78.17498	30.49609	78.17497	3.225984

Table 3.13: Result after second elimination process

Sr.No.	Location	Latitude	Longitude	Latitude	Longitude	Distance in m
1	1-2	30.5137	78.14283	30.51368	78.14283	0.426022
2	1-2	30.50744	78.14238	30.50742	78.14238	0.426037
3	1-3	30.51147	78.14327	30.52594	78.16697	2655.589
4	1-3	30.51146	78.14327	30.52594	78.16697	2655.617
5	1-4	30.51071	78.14327	30.50498	78.16079	1952.641
6	1-4	30.51071	78.14327	30.50497	78.16079	1952.656
7	1-5	30.51071	78.14327	30.49675	78.15411	1246.47
8	1-5	30.51071	78.14327	30.49693	78.15412	1246.501
9	2-3	30.51106	78.16274	30.52511	78.16703	574.1916
10	2-3	30.51106	78.16274	30.52504	78.16704	574.2273
11	2-4	30.50475	78.16082	30.50494	78.16079	5.343896
12	2-4	30.50475	78.16082	30.50495	78.16079	5.523958
13	2-5	30.50163	78.1561	30.50169	78.1561	1.418074
14	2-5	30.50492	78.16096	30.50485	78.16097	1.751752
15	3-4	30.51745	78.17447	30.51317	78.17442	97.66438
16	3-4	30.51748	78.17436	30.5132	78.17431	97.66528
17	3-5	30.51885	78.1712	30.50361	78.17078	350.3707
18	3-5	30.51885	78.1712	30.50359	78.17081	350.3936
19	4-5	30.49621	78.17495	30.49609	78.17497	3.148507
20	4-5	30.49622	78.17498	30.49609	78.17497	3.225984

can be concluded that, this location is not in a vicinity of any location (that is within 2 km distance for any nearest location. In that case the location next ZigBee (first is at center of location) for this location is on one of the GPS Coordinate on the perimeter of circle. The location of GPS Coordinate on the perimeter of circle will be the GPS Coordinate giving minimum distance. Thus for this location; whose circle is not intersecting; all other GPS Coordinates except the nearest are of again no practical importance. Thus, the Table 3.14 will modify as following and 20 probable points are reduced to 12 probable points.

Table 3.14: Result after Third elimination process

Sr.No.	Location	Latitude	Longitude	Latitude	Longitude	Distance in m
1	1-2	30.5137	78.14283	30.51368	78.14283	0.426022
2	1-2	30.50744	78.14238	30.50742	78.14238	0.426037
3	1-3	30.51147	78.14327	30.52594	78.16697	2655.589
4	1-3	30.51146	78.14327	30.52594	78.16697	2655.617
5	1-4	30.51071	78.14327	30.50498	78.16079	1952.641
6	1-4	30.51071	78.14327	30.50497	78.16079	1952.656
7	1-5	30.51071	78.14327	30.49675	78.15411	1246.47
8	1-5	30.51071	78.14327	30.49693	78.15412	1246.501
9	2-3	30.51106	78.16274	30.52511	78.16703	574.1916
10	2-3	30.51106	78.16274	30.52504	78.16704	574.2273
11	2-4	30.50475	78.16082	30.50494	78.16079	5.343896
12	2-4	30.50475	78.16082	30.50495	78.16079	5.523958
13	2-5	30.50163	78.1561	30.50169	78.1561	1.418074
14	2-5	30.50492	78.16096	30.50485	78.16097	1.751752
15	3-4	30.51745	78.17447	30.51317	78.17442	97.66438
16	3-4	30.51748	78.17436	30.5132	78.17431	97.66528
17	3-5	30.51885	78.1712	30.50361	78.17078	350.3707
18	3-5	30.51885	78.1712	30.50359	78.17081	350.3936
19	4-5	30.49621	78.17495	30.49609	78.17497	3.148507
20	4-5	30.49622	78.17498	30.49622	78.17497	3.225984

6. **Final elimination:** In the last process of optimization, the objective is to obtain the minimum number of nodes for the placement of ZigBee.

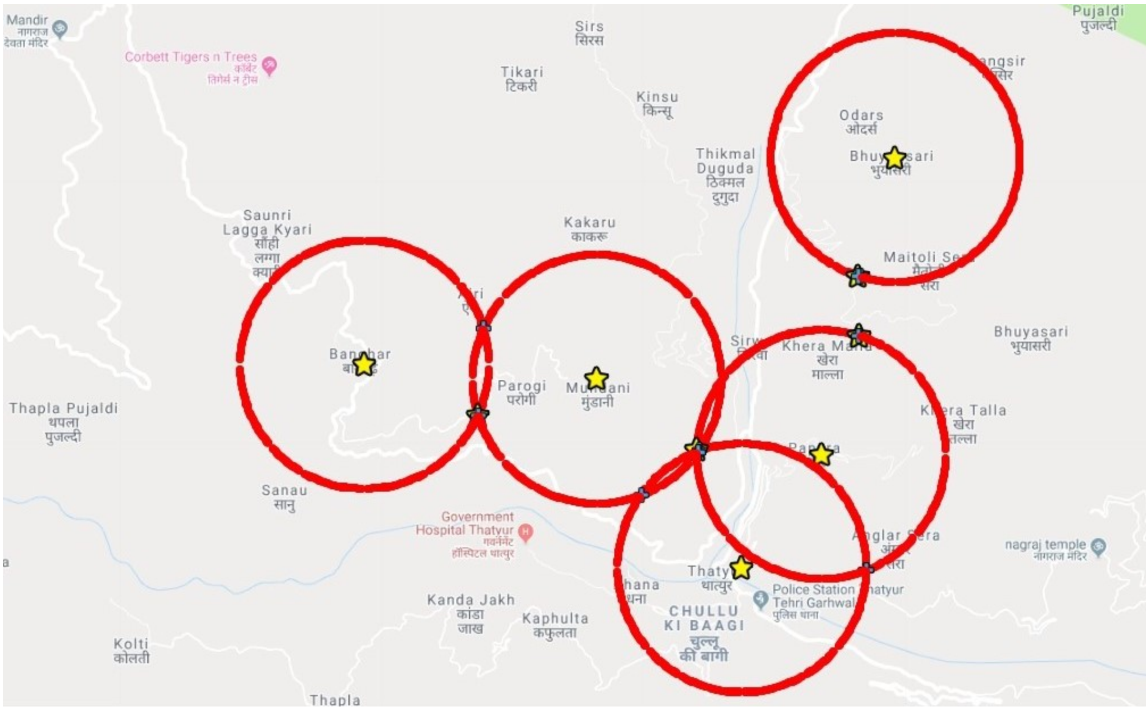

Figure 3.20: Plot of all circle GPS coordinates, village centers and elimination results

The logic used for this optimization is, to calculate the total distance joining all 17 GPS Coordinates (12 GPS Coordinates as per Table 3.14 and five village centers, total 17 GPS Coordinates), with the constrain that, if there are more than two GPS Coordinates within 1 km from the previous points, then only one of them will be considered at a time. To calculate the distance, the process is started with Village 1's center to the next points within one kilometer (that can be either on circle of village 1 or within the circle of village 1) to the next adjoining point (again within 1 km) and so on till the destination location, that is Village Thatyur. The process is repeated for all village's centers with the same constrain as mentioned above and Thatyur as destination for each path combination.

The result of last process of optimization are as shown in Table 3.15

3.4.9.1 RESULT OF STEP III OF OPTIMIZATION

The result of Table 3.15 and centers of all villages is as shown in Fig. 3.21. It can be observed that, with the help of optimization, the probable 5560 GPS Coordinates are reduced to just 4 final GPS Coordinates. Table 3.16 gives the final GPS Coordinates of 'Four' ZigBee's and five ZigBee's for the villages.

The final optimization result and data transmission for each village will be transmitted as per route in Table 3.17 and plotted on Google Map as shown in Fig. 3.22.

Table 3.15: Result after Final elimination process

Sr.No.	Location	Latitude	Longitude	Latitude	Longitude	Distance in m
1	1-2	30.5137	78.14283	30.51368	78.14283	0.426022
2	1-2	30.50744	78.14238	30.50742	78.14238	0.426037
3	1-3	30.51147	78.14327	30.52594	78.16697	2655.589
4	1-3	30.51146	78.14327	30.52594	78.16697	2655.617
5	1-4	30.51071	78.14327	30.50498	78.16079	1952.641
6	1-4	30.51071	78.14327	30.50497	78.16079	1952.656
7	1-5	30.51071	78.14327	30.49675	78.15411	1246.47
8	1-5	30.51071	78.14327	30.49693	78.15412	1246.501
9	2-3	30.51106	78.16274	30.52511	78.16703	574.1916
10	2-3	30.51106	78.16274	30.52504	78.16704	574.2273
11	2-4	30.50475	78.16082	30.50494	78.16079	5.343896
12	2-4	30.50475	78.16082	30.50495	78.16079	5.523958
13	2-5	30.50163	78.1561	30.50169	78.1561	1.418074
14	2-5	30.50492	78.16096	30.50485	78.16097	1.751752
15	3-4	30.51745	78.17447	30.51317	78.17442	97.66438
16	3-4	30.51748	78.17436	30.5132	78.17431	97.66528
17	3-5	30.51885	78.1712	30.50361	78.17078	350.3707
18	3-5	30.51885	78.1712	30.50359	78.17081	350.3936
19	4-5	30.49621	78.17495	30.49609	78.17497	3.148507
20	4-5	30.49622	78.17498	30.49622	78.17497	3.225984

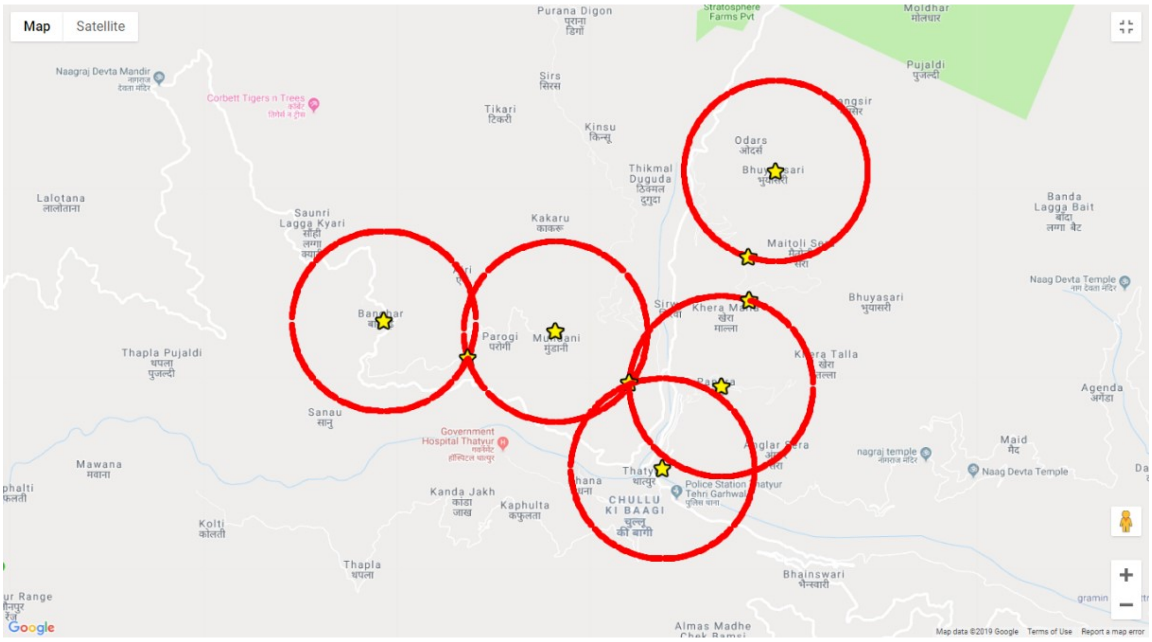

Figure 3.21: Final GPS coordinates of ZigBee

Table 3.16: GPS Coordinates for the location of ZigBee

Sr.No.	Tag	Latitude	Longitude	Location Name
1	1	30.51109	78.13284	Village: Banghar
2	2	30.51003	78.15237	Village: Mundani
3	3	30.52608	78.17741	Village: Bhuyasari
4	4	30.50461	78.17122	Village: Papara
5	5	30.4964	78.16454	Village: Thatyur, The Destination
6	6	30.50742	78.14238	Intermittent GPS Coordinate
7	7	30.50495	78.16079	Intermittent GPS Coordinate
8	8	30.51317	78.17442	Intermittent GPS Coordinate
9	9	30.51748	78.17436	Intermittent GPS Coordinate

Table 3.17: Route for data transmission from various villages

Village	Route	Destination
Banghar	1-6-2-7-5	Thatyur
Mundani	2-7-5	Thatyur
Bhuyasari	3-8-9-4-7-5	Thatyur
Papara	4-7-5	Thatyur

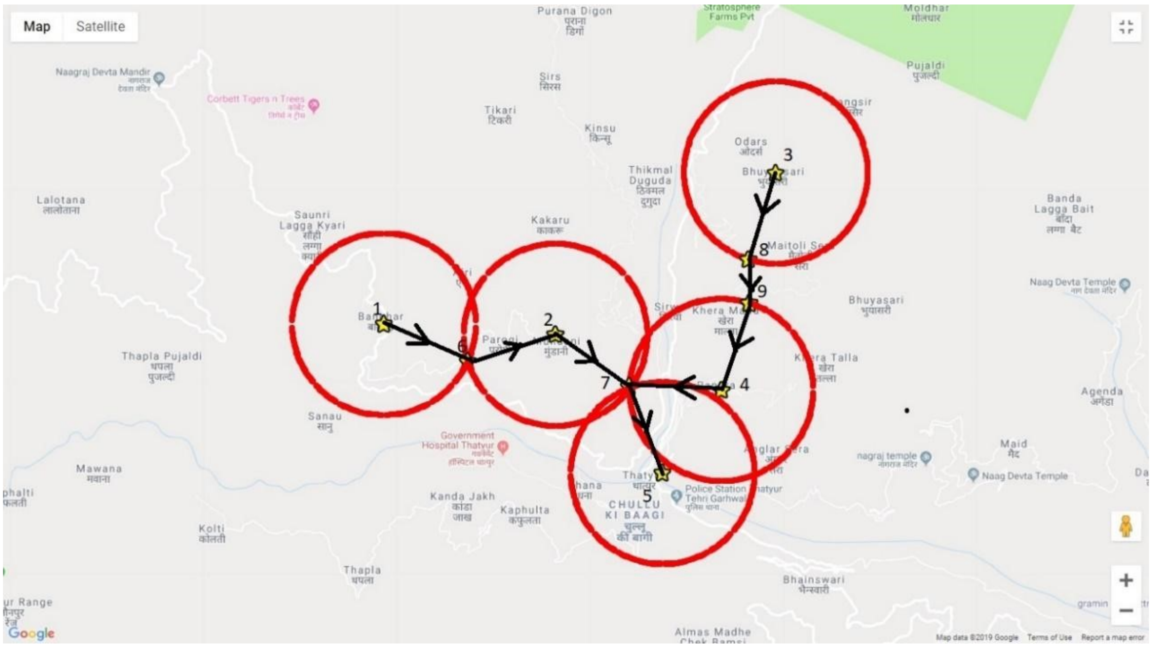

Figure 3.22: The route for data flow from each villages

3.4.10 COMPARISON OF RESULTS:

Table 3.9 gives the number of ZigBees required for data transmission without optimization. It is seen that we would have required around 8 Nos of Intermediate ZigBee , however, with the help of new algorithm, Table 3.16, we can see that, the same purpose of data transmission can be solved with the help of only Four ZigBee and also the new algorithm has also given the exact location of placement of ZigBee, which is a challenging task, without Optimization. Thus with the developed algorithm in the research work, it is possible to optimize and minimize the required GPS Coordinates for the purpose of data communication.

With the help of developed algorithm in the research work and applied to case study, the data from five remotely and distinctly located villages can been communicated to the requisite location, with the help of just four intermittent communicable devices.

3.5 FINANCIAL IMPLICATION FOR ENERGY INDEPENDENCE OF VILLAGES:

The previous sections of chapter discusses about the available energy potential at villages, Power plant sizes and optimization of WLAN using new developed algorithm. With the findings of above results a financial model is described here, so as to make villages Energy Independence. Table 3.8 describes the sizes of Power plants. This table described the sizes of power plant to meet the electrical energy requirement. However, as we are aware that apart from Electrical energy, energy is required for heating, cooking etc. The heating energy is required for water heating and cooking. At present, villages use cow dung or firewood available in nearby forest. In this research proposal, a biogas/biomass plant will be installed. This plant will provide the biogas for cooking purpose and any excess gas generated will be used for running of DG set. Solar water heaters of 100 Liters capacity are installed for each house, so as to meet the hot water requirement. Table 3.18 shows the total proposed energy installations at individual villages.

Table 3.18: Total estimated energy requirement of villages.

Type of Power Plant	Banghar (42 Houses)	Mundani (55 Houses)	Bhuyasari (62 Houses)	Papara (66 Houses)
Solar Power Plant	20 kWp	20 kWp	20 kWp	20 kWp
Wind Power Plant	5 kW	5 kW	5 kW	5 kW
Battery Bank	100 kWh	100 kWh	100 kWh	100 kWh
DG Set	20 kW	20 kW	20 kW	20 kW
Solar WH System	4200 Lts	5500 Lts	6200 Lts	6600 Lts
Biogas Plant	40 m^3	40 m^3	40 m^3	40 m^3

The capacity of solar hot water system is approximated, as a thumb rule. A 100 Litre water heating system provides sufficient hot water to a family of 4-6 persons. Thus, on an average a 100 Liter hot water system is provided.

The biogas plant capacity is estimated based on basic calculation:

1. one cattle produces approximately 10 kg dung per day.
2. on an average there are 25 cattles per villages
3. Total of approximately 250 kg of cattle dung is produced per day.

4. On an average 25 kg of cattle dung produces 1 cubic meter of BioGas (Methene-CH_4)

5. Thus, around 10 cubic meter of gas will be produced per day.

6. This gas is sufficient to cook food for family of 4-6.

7. Any excess gas can be used to operate the DG set. one Cubic meter of this gas produces 6 kWh of heat energy. With 50 % efficiency of DG set, the 10 cubic meter of gas will generate around 30 kWh of Energy.

8. In case of Emergency, Diesel can be used to operate the DG set.

The financial implication for each village can be estimated as in Table 3.19

Table 3.19: Total estimated financial requirement of villages.

Type of Power Plant	Banghar (42 Houses)	Mundani (55 Houses)	Bhuyasari (62 Houses)	Papara (66 Houses)
Solar Power Plant	8 Lakhs	8 Lakhs	8 Lakhs	8 Lakhs
Wind Power Plant	4 Lakhs	4 Lakhs	4 Lakhs	4 Lakhs
Battery Bank	6 Lakhs	6 Lakhs	6 Lakhs	6 Lakhs
DG Set	1 Lakh	1 Lakh	1 Lakh	1 Lakh
Solar WH System	2.4 Lakhs	3 Lakhs	3.6 Lakhs	3.8 Lakhs
Biogas Plant	3 Lakhs	3 Lakhs	3 Lakhs	3 Lakhs
Total	24.4 Lakhs	25 Lakhs	25.6 Lakhs	25.8 Lakhs

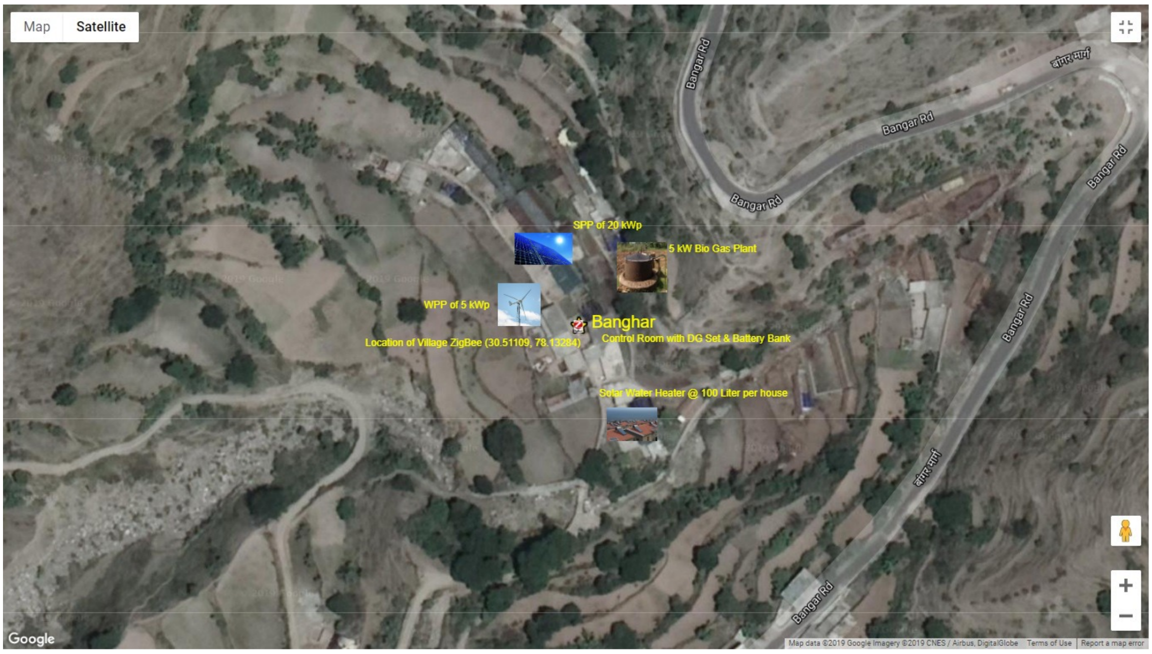

Figure 3.23: Representation of Banghar village with power Plants

3.6 CHAPTER SUMMARY

This Chapter gives describes the details of the various Optimization process. Some of popular Optimization processes are described at the beginning of chapter. The chapter also describes the challenge in data communication from remote location and application of optimization technology for the same. The problem related with selection of Coordinates has been described for a Cartesian Coordinate system with center of destination as origin. The solution for Cartesian coordinate system has been obtained through two optimization methods; GA and PSO and results are the same are compared. However, the solution had obtained in Cartesian coordinate system, the real GPS Coordinates on the need to be addressed. In practical case, the location of remotely located power system with be having some specific GPS Coordinate(s) and then through these GPS coordinate we have to find the shortest distance.

To find the shortest path in terms of GPS coordinate, the algorithm has to be modify with the help of Haversine formula. This modified algorithm is applied to a case study of five remotely located villages. From the results of optimization, it can be observed that, with the help of just four intermediate ZigBee devices, the data from four villages can be transferred to the destination location. In short, Chapter describes the Optimization algorithm and process.

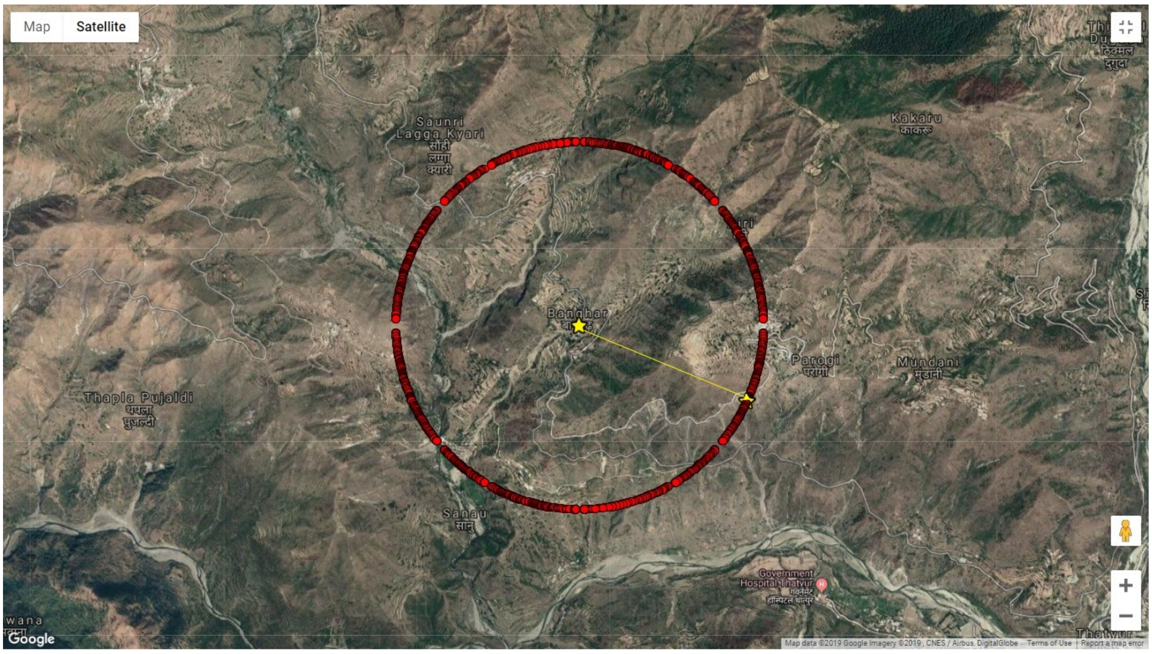

Figure 3.24: Representation of ZigBee at Banghar village and next communicating ZigBee

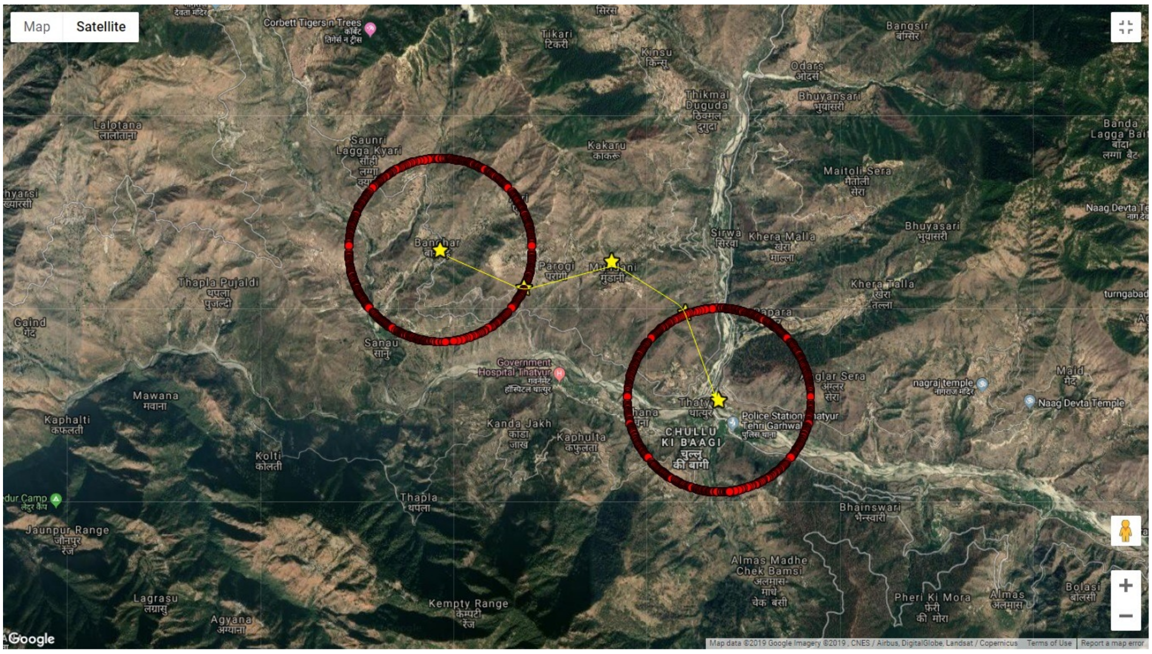

Figure 3.25: Data communication path from Banghar to Thatyur

Figure 3.26: Representation of Mundani village with power Plants

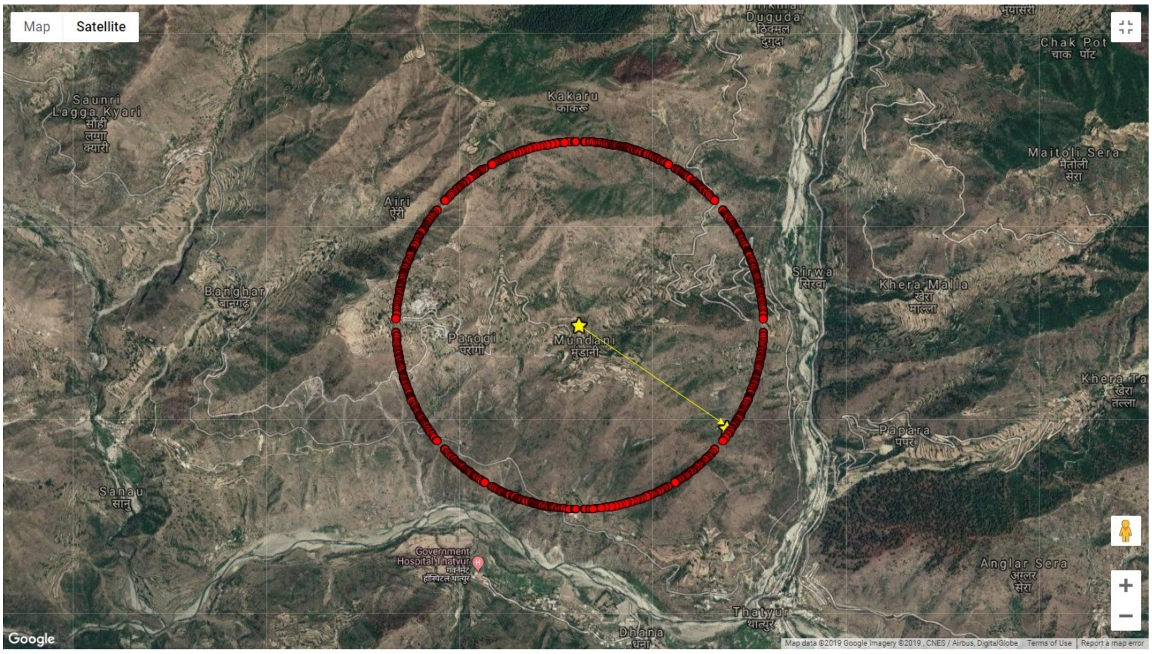

Figure 3.27: Representation of ZigBee at Mundani village and next communicating ZigBee

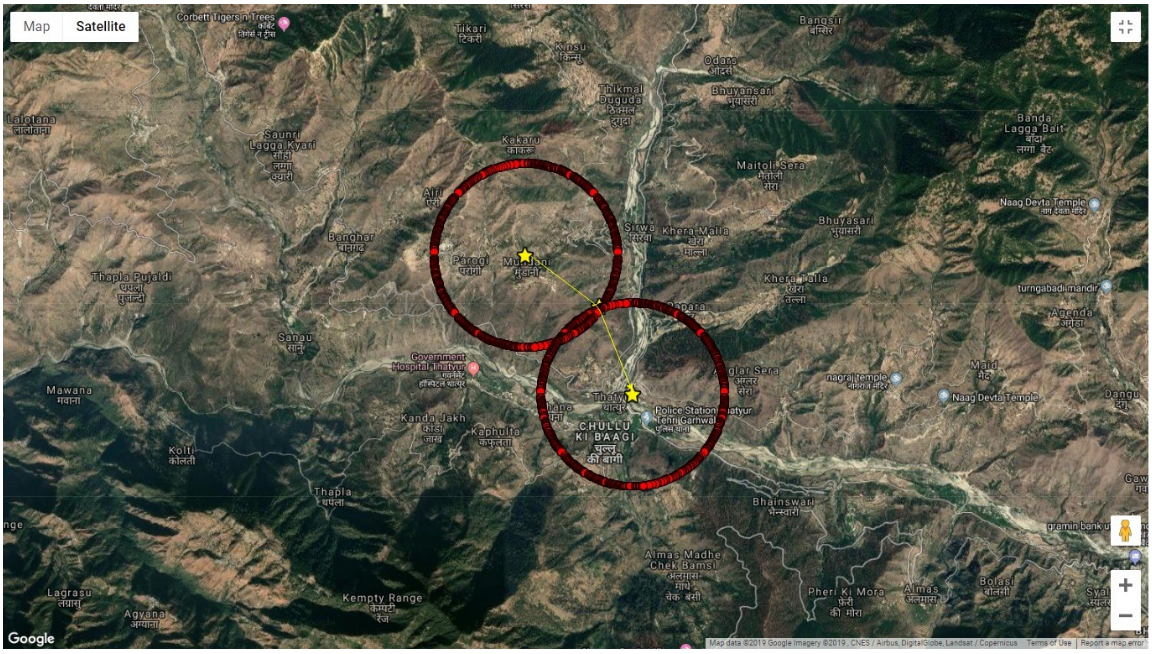

Figure 3.28: Data communication path from Mundani to Thatyur

Figure 3.29: Representation of Bhuyasari village with power Plants

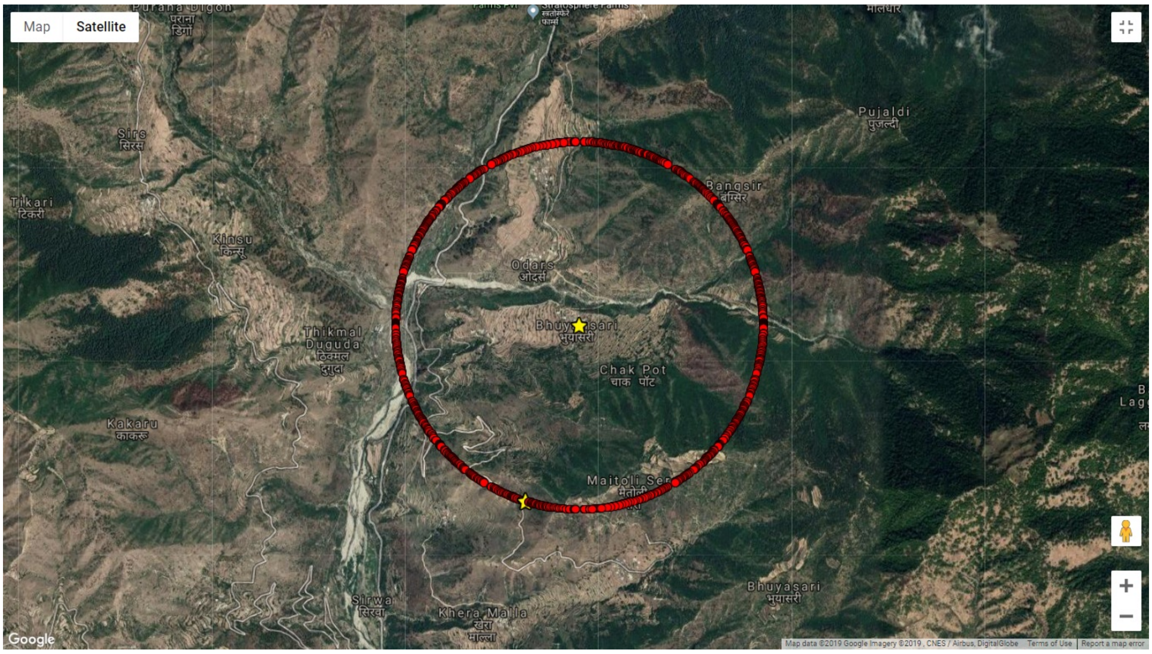

Figure 3.30: Representation of ZigBee at Bhuyasari village and next communicating ZigBee

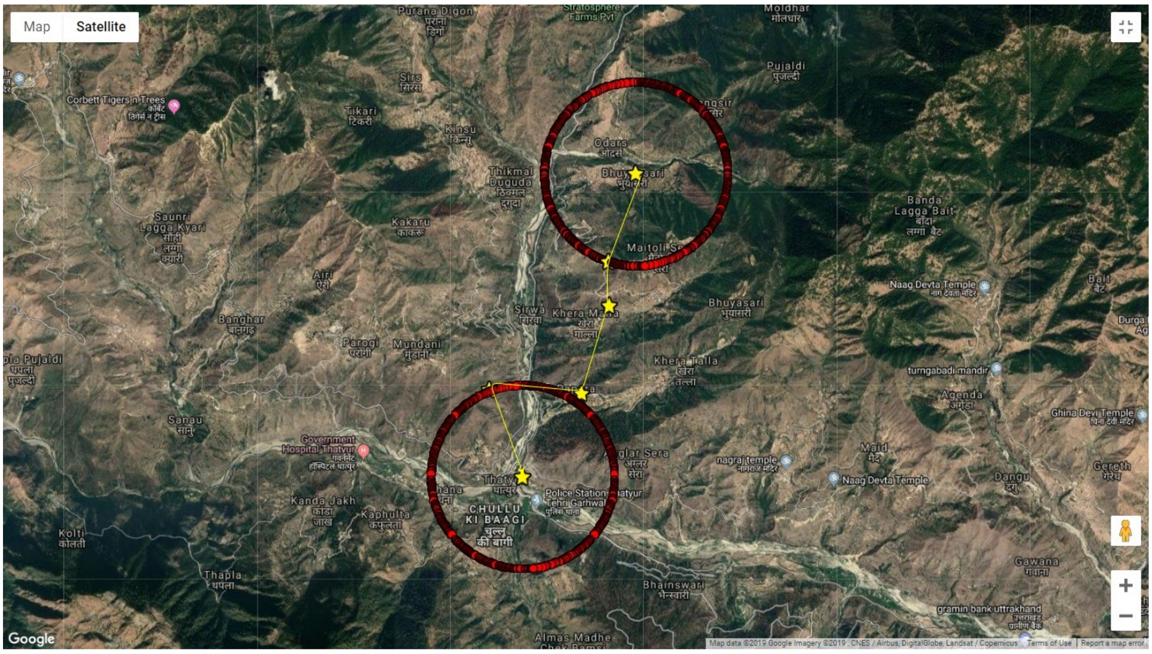

Figure 3.31: Data communication path from Bhuyasari to Thatyur

Figure 3.32: Representation of Papara village with power Plants

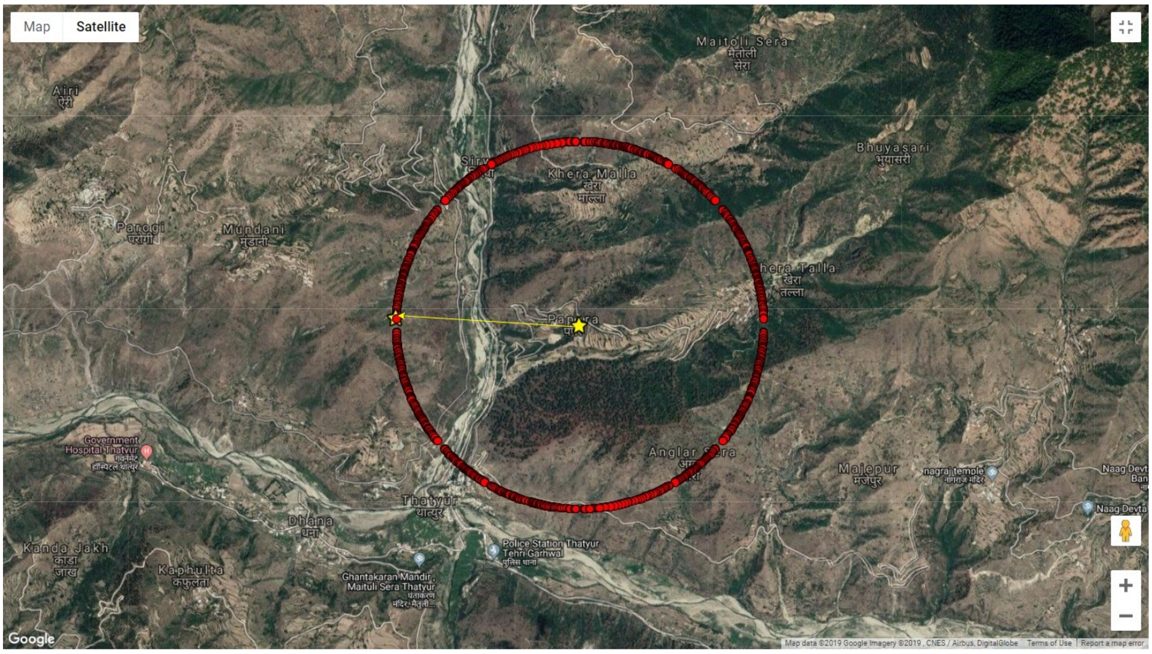

Figure 3.33: Representation of ZigBee at Papara village and next communicating ZigBee

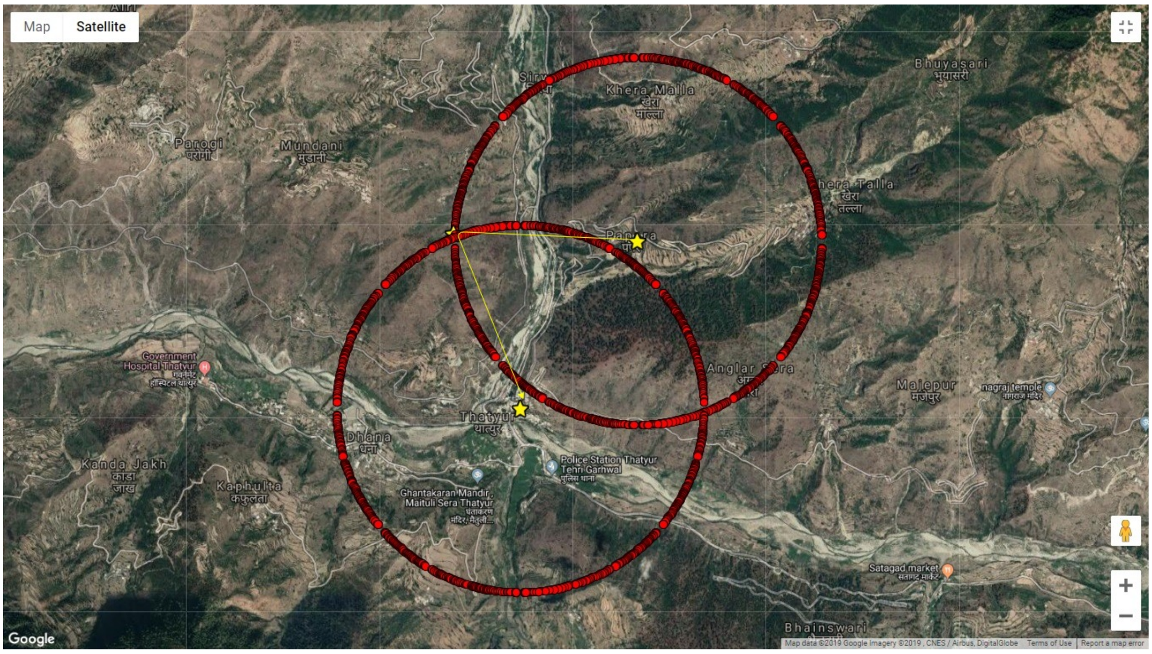

Figure 3.34: Data communication path from Papara to Thatyur

CHAPTER 4

HARDWARE DESCRIPTION

As discussed in previous chapter, with the help of developed algorithm, the minimum number nodes has been identified. In this research work, this chapter describes the hardware circuitry with suitable coding.

A system is designed and developed to measure, monitor and control the specified parameter for a particular technological system. Two Electrical Power Generating units are controlled using the research work. The electrical power generating units are 'micro hydro' and 'solar panels'. Basically Voltage, Current and Phase Angle between voltage and current are sensed using sensor network. These basic parameters primarily provide all required information related to a power station to take an immediate action (ON/OFF)[80,81]. These sensed parameters are connected to signal conditioning block and through isolator it is connected to DA Card. It is assumed that one of electrical generation station (Solar) is within the accessible GSM network and other electrical station is not within the reach of GSM network. The model representing parameter sensed from solar station, which is within reach of GSM network, is connected to the GSM communicating network, through which parameters are transmitted over long distance is represented in Fig. 4.1.

It is pretended that, the micro hydro station is at remote location and there is no access for GSM or any other communication network. In such case, the DAC of Hydro station is connected to the WLAN and through which it is transmitted over specified distance using this WLAN technology. The receiver at the specified distance receives the data and that will be connected to coordinator which is integrated with GSM communication network [82,83].

The GSM network with transmit the data globally, for both the nodes. Refer Figs. 4.2 - 4.4.

When the network coordinator receives the sensor information from the sensor module, it forwards the information to the connected gateway. On the other hand, the coordinator also receives the control command from the gateway. When the control command is received, the network coordinator forwards the control command to the corresponding control device of the wireless sensor network to execute the command. The gateway works as a translator and synchronizer between the wireless sensor network and the web ser-

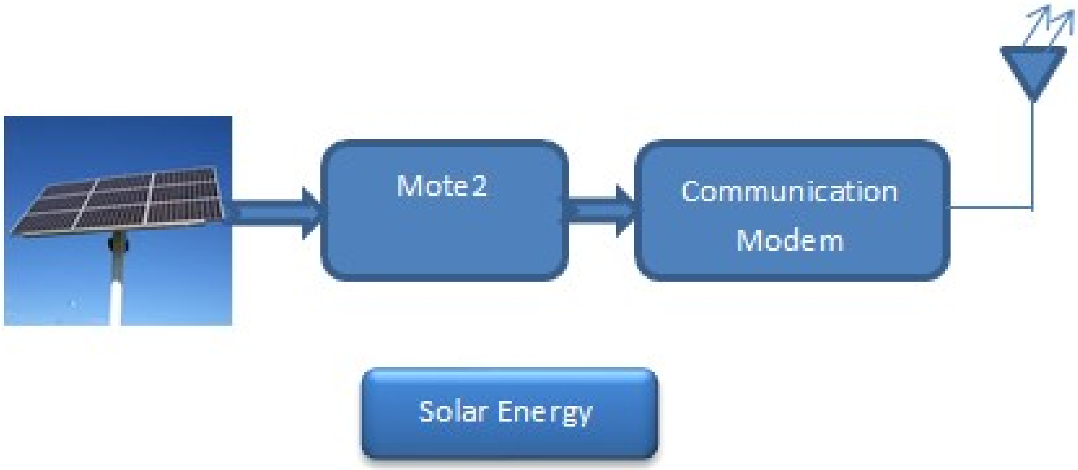

Figure 4.1: Data transmission for the solar power station (in GSM vicinity)

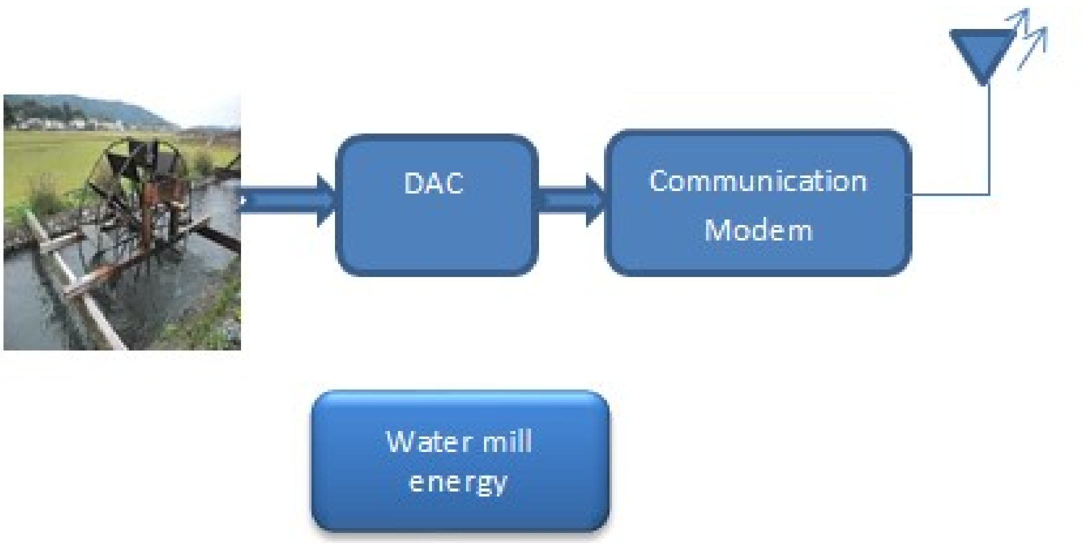

Figure 4.2: Data transmission for the micro hydro station through WLAN

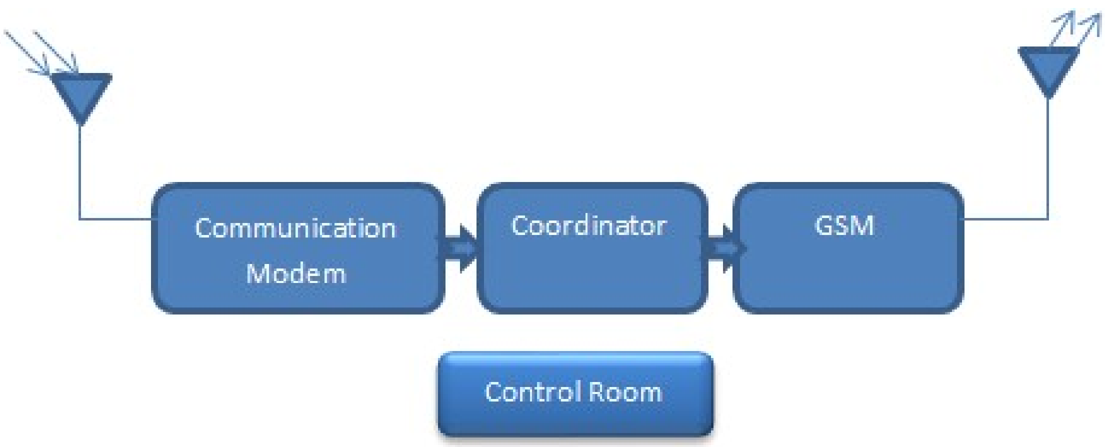

Figure 4.3: Data received from WLAN for the micro hydro station and connected to GSM

Figure 4.4: GSM network transmitting data globally

vice. It communicates with the wireless sensor network via the connection of the network coordinator.

4.1 CIRCUIT DIAGRAM

From Fig. 4.5, Arduino Uno is being powered up by 12V regulated power supply using 7812 IC. Voltage and current sensor are connected to the analog pin of Arduino Uno in pin no. A0 and A1. The analog values of the sensors are being processed by the code and the processed data is being transmitted wirelessly via Tx pin of Arduino Uno and the same is been displayed in the LCD locally in the circuit given in Fig. 4.5. The signals from the voltage and current sensors are received by the input pins of Arduino[85]. A microcontroller and a de-multiplexing circuit is also used. In this case, the signals are pulse width modulated for communication.

4.2 ARDUINO PLATFORM

An Arduino is very commonly used low cost, open-source prototype platform. It is combined with microcontroller which can read input from both analog and digital devices

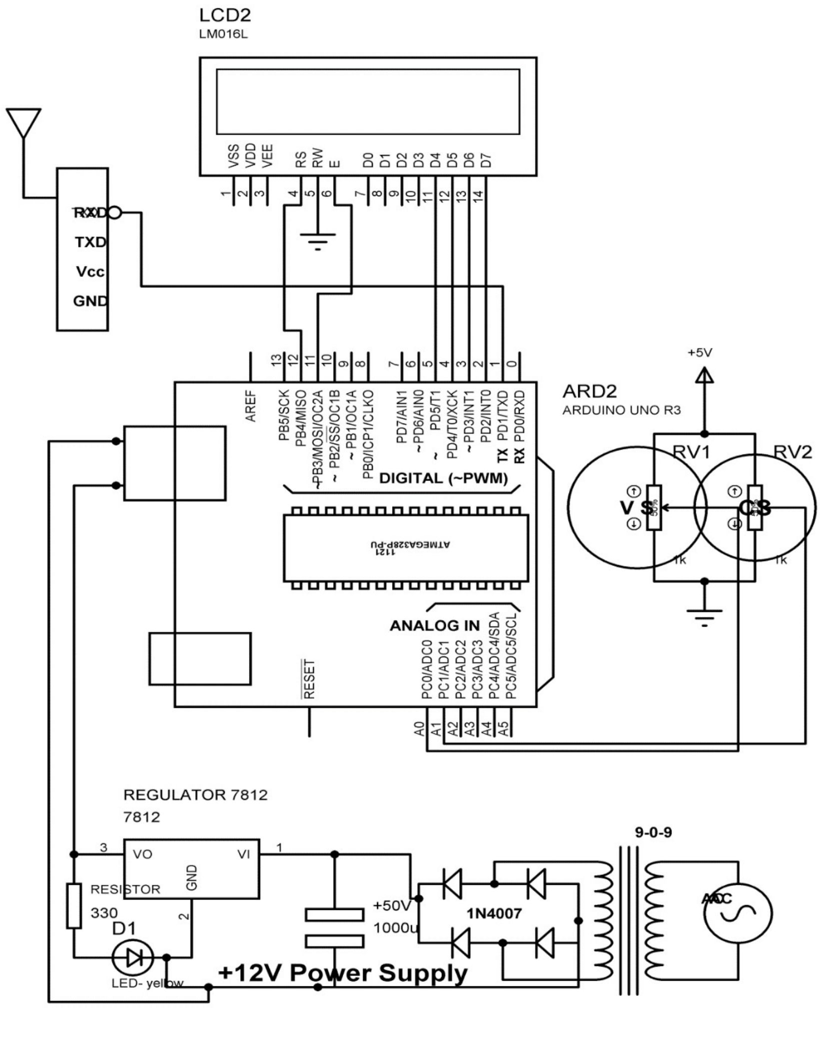

Figure 4.5: Hardware circuit of voltage and current sensing and transmitting system

such as sensors and digital circuits. Based on data received serially it can take action in a system. Arduino-IDE provides drivers, wiring language same as C++, boards and all necessary support or additional source of coding can be easily coded and used directly.

Arduino applications are of wide range from simple sensor data analysis to any scientific Instrument application. It can be used by any professional irrespective of any branch of science and has become common module for thousands of projects. Musicians, Students, Programmers, Hobbyists, Professionals are gathered around Arduino platform and have contributed a lot of scope and role in their areas.

The revolution of the Real time data monitoring has brought many challenges to be solved by automation for which an embedded solution is under search. Arduino finds its place the scenario to replace the traditional techniques and gives a low cost embedded solution as in case of prototyping or it is part of large system. Arduino applications include 3D printing, health bands, Internet of Things (IoT), automatic switches, Robotics, Drones, Navigation, Sensor connectivity, etc. Arduino software runs on all operating systems like Windows, Mac, Android and Linux. Educational institution prefers Arduino boards for demonstrating experiments, Principles of Physics, Chemistry and in Robotics. Arduino community helps users to exchange knowledge and share ideas for betterment of society.

Arduino simplifies the process of working with microcontrollers. Some major advantages are:

1. Inexpensive
2. Cross-platform
3. Simple, clear programming environment
4. Open source and extensible software
5. Open source and extensible hardware

4.2.1 ARDUINO UNO RS

1. The Arduino Uno is a microcontroller board based on the Atmel's ATmega328
2. It has 14 digital input/output pins out of which 6 can be used as PWM outputs and 6 for analog inputs.
3. The Power supply to Arduino Uno is either via USB connection or with an external power supply.
4. It contains everything needed to support the microcontroller; it simply needs to be connected it to a computer with a USB cable.

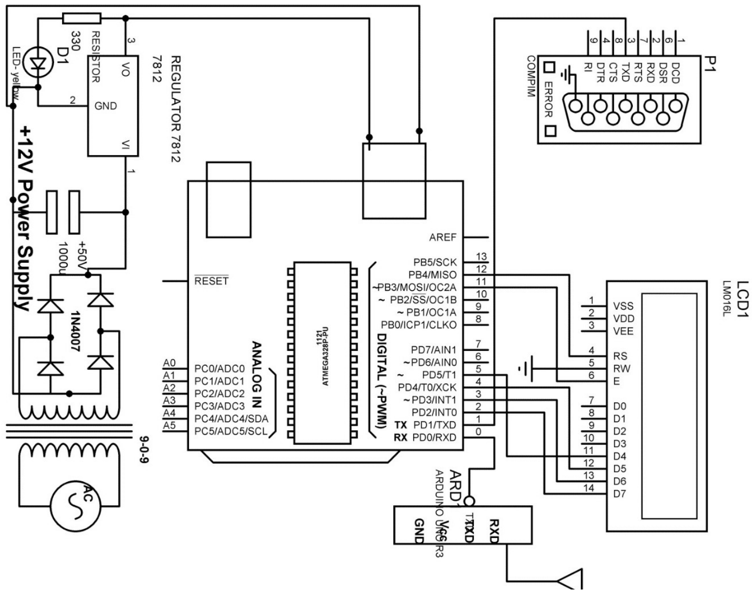

Figure 4.6: Hardware design of the Arduino board

5. Arduino IDE supports Windows, Mac OS X or Linux.

In the Fig.4.6, Arduino Uno has been powered up by 12V regulated power supply using 7812 IC. The processed analog values of the sensors are being received wirelessly at Rx pin of Arduino Uno is transmitted serially to computer via COMPIN and the same is been displayed in LCD locally.

4.3 HARDWARE CIRCUIT DIAGRAM OF RECEIVING SYSTEM

In case of receiving circuit, the basic IC hardware is same. But here a receiver is used which is receiving the modulated signals and then demodulating them. The Arduino is also connected to the LCD and to a ZigBee. The digital pins of the Arduino are connected to the digital pins of the LCD.

In the Fig. 4.7, Arduino Uno has been powered up by 12V regulated power supply using 7812 IC. The processed analog values of the sensors are being received wirelessly at Rx pin of Arduino Uno is transmitted serially to computer via COMPIN and the same is been via GSM Modem and also been displayed in LCD locally. In this hardware circuit, a GSM modem is connected which receives the main signal and transmits it further to the console. In this also, regulated input supply is given. And an LCD is connected to the controller circuit.

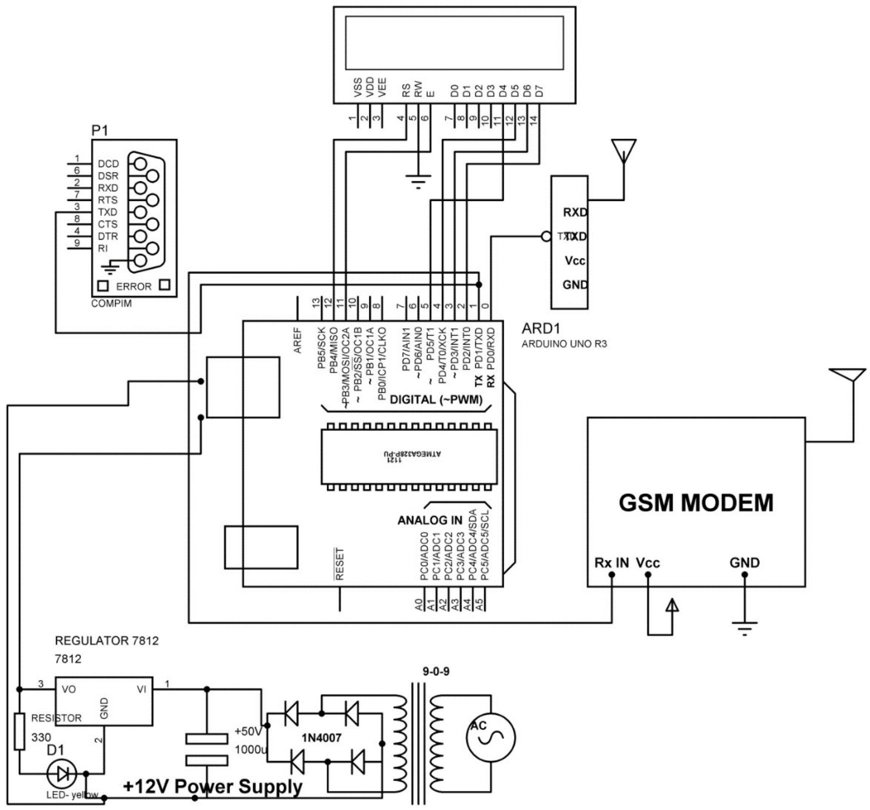

Figure 4.7: Hardware circuit diagram of receiving system

4.4 GSM MODULE

GSM modem provides serial communication interface to send/ receive the messages to computer for proper action by destination device. GSM (Global System for Mobiles) and GPRS(Global Packet Radio Service) architecture is used by mobile communication for transmitting and receiving important via ports like RS-232 and USB. The MODEM is core in such applications.

GSM/GPRS MODEM slotted with SIM (Subscriber Identity Module) which operate on availability of cellular network and GPRS network. GSM/ GPRS perform following operations:

1. Sending SMS, Receiving and or Deletion of a SIM.
2. Read, Write entries of the SIM.
3. Voice calls establishment and release.

The MODEM requirements are to get AT commands to interact with CPU on hyper terminal. These commands are sent by the controller. The result is send back by the MODEM after receiving respective command. To interact with the GSM and GPRS cellular

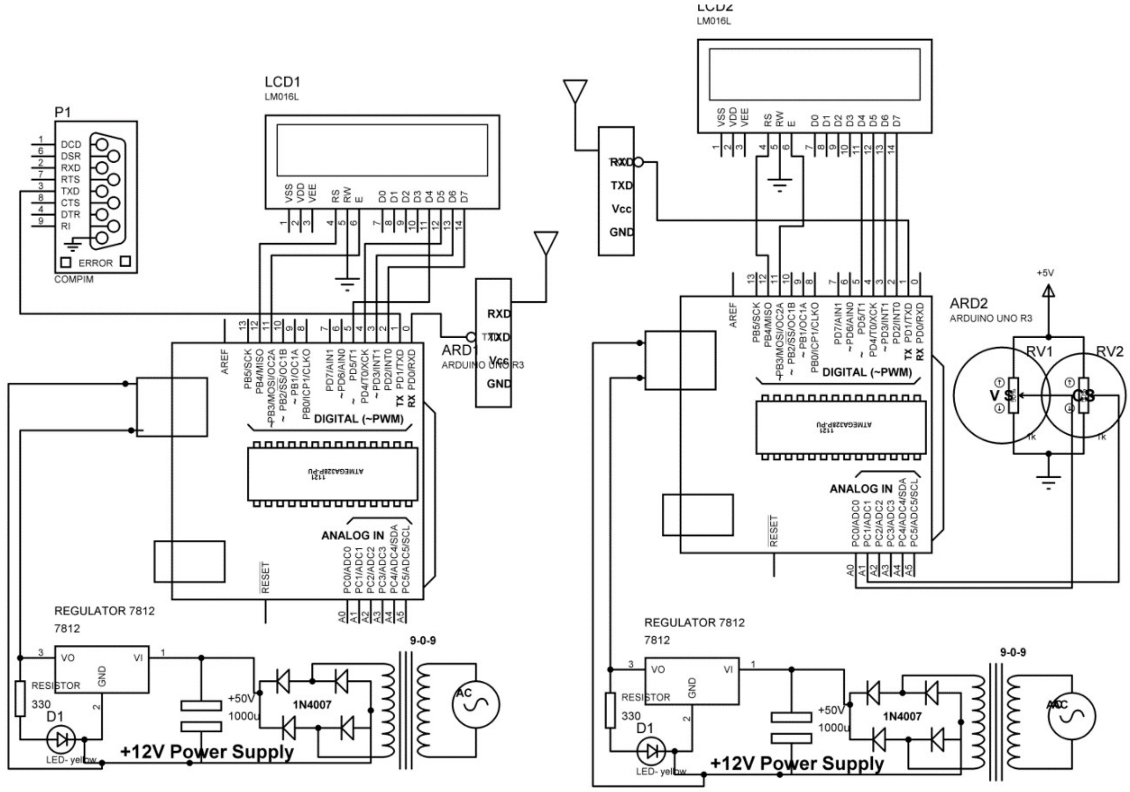

Figure 4.8: Hardware circuit of transmitting system and receiving system

network, Different AT commands are issued for proper action by processor and transfer data through RS232, SPI, USB and etc.

4.4.1 HARDWARE CIRCUIT OF RECEIVING SYSTEM WITH GSM MODEM

The circuit diagram of the system is as shown in Fig. 4.8. In the transmitting module analog pins (A0, A1) of Arduino is connected to the current sensor and voltage sensor respectively. The USART Tx pin of Arduino of transmitting module is connected to the USART Rx pin of ZigBee modem. The digital pins D2, D3, D4, D5 of Arduino of transmitting module is connected with digital pin of D14, D13, D12, D11 respectively and digital pin D5 of LCD is grounded and D4, D6 are connected with D12, D11 of Arduino.

Similarly, at receiver side digital pin of Arduino D2, D3, D4, D5, D11, D12 are connected with digital pin of LCD D14, D13, D12, D11, D6 and D4 respectively. D5 of LCD is grounded. USART Rx pin of Arduino of receiver side is connected with USART Tx pin of ZigBee modem. USART TX of Arduino of receiver is connected with USART Tx.

4.5 MODELING USING PROTEUS

Simulation plays an important role in designing and execution of all projects that are formed with the help of controllers. It can be easily configured with a wide range of architectures and also produce result from them. Customization of the architecture is also easily done with the help of Proteus. It basically connects the nodes of the controller via an interconnection channel.

Proteus simulation involves the basic four steps:

1. Firstly, the architecture is specified by the user using a configuration tool which is X based.
2. A link is formed between the application software and the architecture layer.
3. The program is then run by the user to produce the output.
4. Proteus generates a graphical output of the executable.

4.5.1 PROTEUS SOFTWARE:

Proteus is one of the well-known software for simulation of microcontroller based projects. It accommodates wide range of microcontrollers for application development and in embedded designs. The software gives provision to export design to the firm for manufacturing of PCB with supporting packages.

Proteus software package has for Computer Aided Design (CAD) which has two main parts namely ISIS and the circuit design environment with VSM simulator, ARES, the PCB which lab center electronics manufacture. With Proteus, PCB design can be designed with computer assistance, electronic circuits and printed circuit boards. The ISIS, Intelligent Schematic Input System provides simulation facility in electronics.

The library has more than 10,000 electronic components with 6000 Prospice simulation models. User can create his own model and add to the library.

ISIS has features like DC/ AC meters for voltage and current measurement, oscilloscope, Digital Pattern Generator, logic analyzers, timer functions, analog signal generators, communication protocol analyzers (ex: RS232, I2C, SPI). The VSM (Virtual System Modeling) provides circuit simulation and visualization. The SPICE tool of Berkeley SPICE3F5 model and microprocessor systems can undergo simulation and interact with VSM-Engine for results. Button, potentiometer, switches are ordered for real time results by LED status, LCD displays, ”Hot / Cold” wires display.

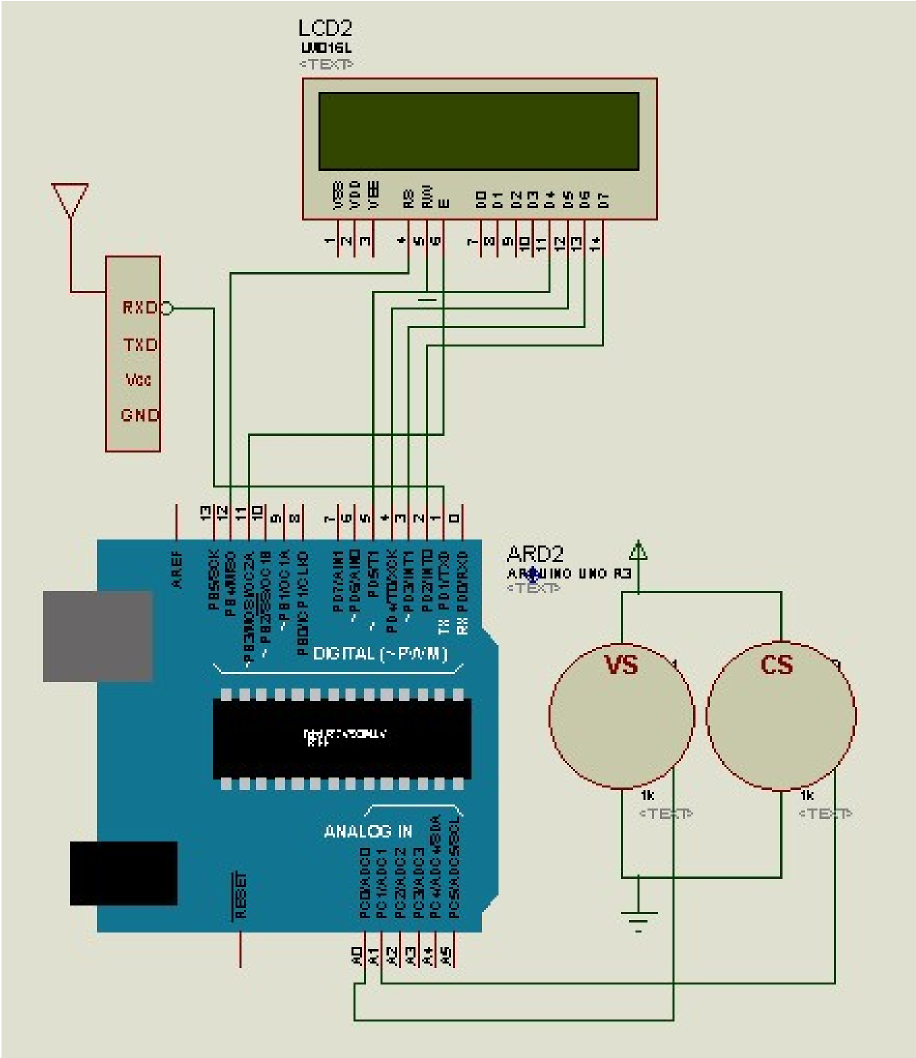

Figure 4.9: Proteus Model for voltage and current sensing and transmitting system

Fig. 4.9 shows Proteus Model for voltage and current Sensing and transmitting System. With the help of this DAC card, the various parameters related to the remotely located power system are sensed and connected to the receiving of ZigBee receiver coordinator Figs. 4.10 and 4.11.

4.6 LabVIEW AS DATA LOGGER FOR ANALYSIS OF SENSORY DATA:

LabVIEW with Arduino is used to record and analyses the sensory data [86,87]. LabVIEW is basically a programming language designed especially for engineers and research work. C and C++ are the complex programming languages. LabVIEW's graphical results

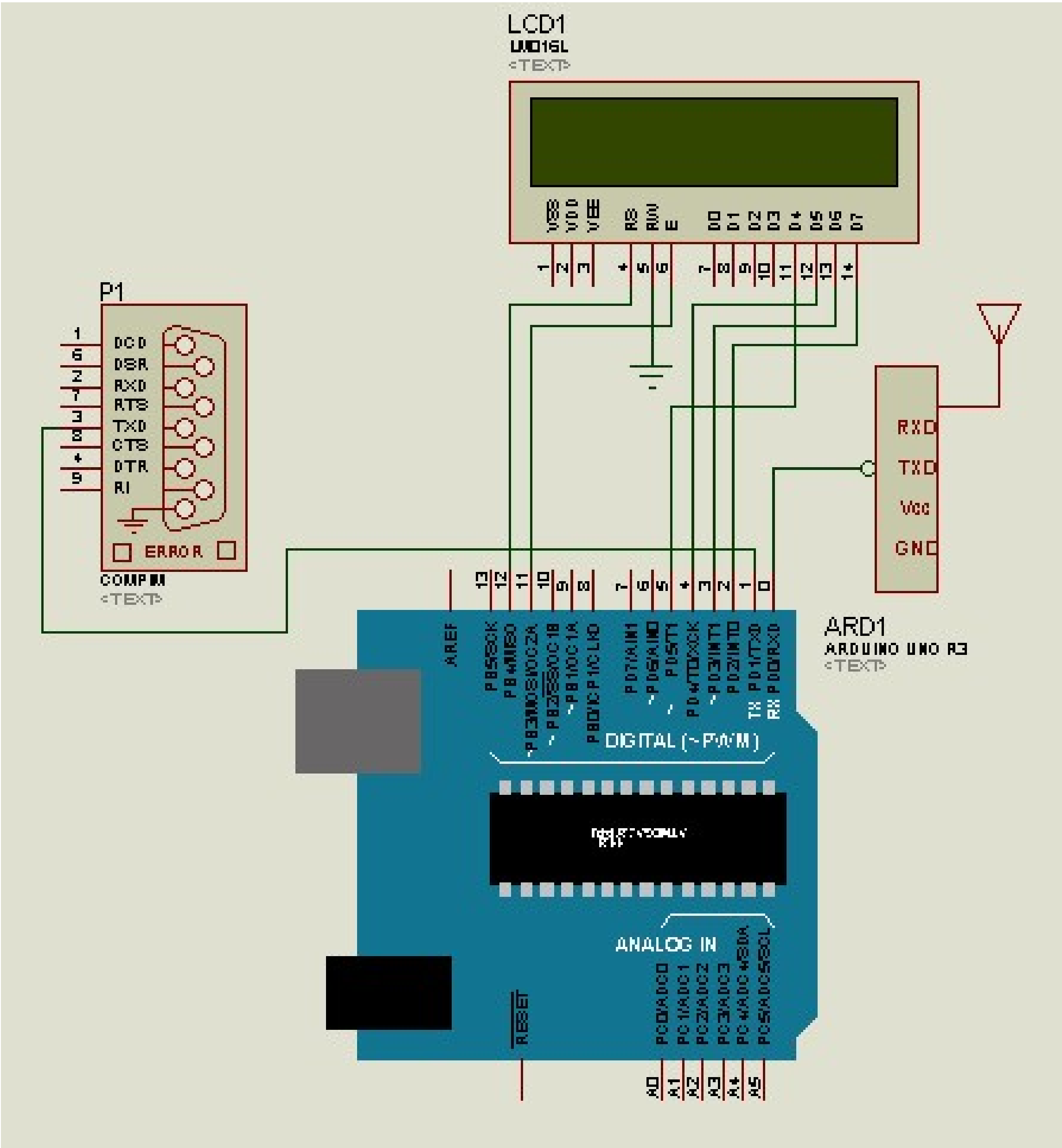

Figure 4.10: Proteus model of receiving system

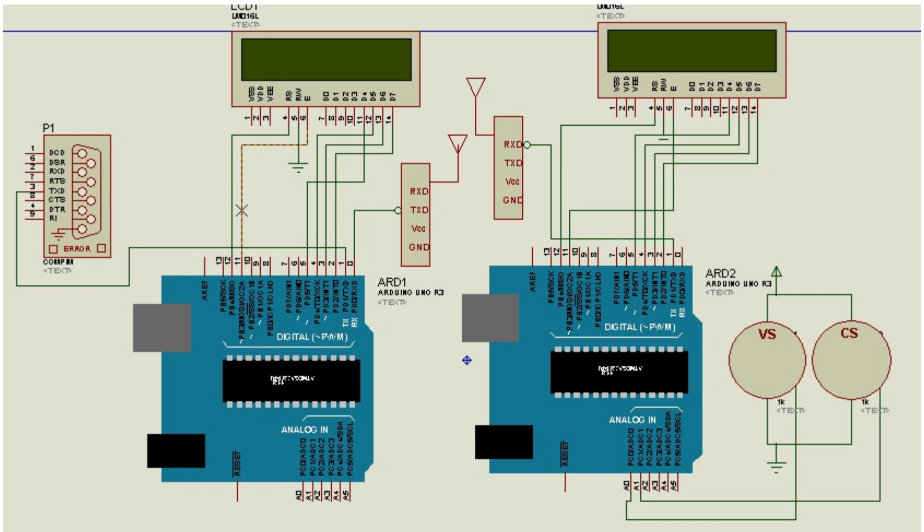

Figure 4.11: Complete proteus model transmitting system and receiving system

can be observed at Virtual Instruments (VIs) blocks. Easy of coding, various serial interfaces like ethernet and USB interfaces is provided by LabVIEW.

VISA consists of several components like VISA serial port. VISA serial read initializes the serial port and reads the specified number of bytes from devices. It also consists of match pattern which searches for regular expression in string pattern.

4.6.1 LabVIEW

LabVIEW is very advanced software with virtual tnstrumentation and graphical features. The application development becomes easy by implementing high acceleration technologies like FPGA, DSP‘s with less effort and physical resource involvement by visual programming facility by National instruments. The signal conditioning Circuit for input to Data Acquisition System, Motor Control, Medical Appliances, IIOT (Industrial Internet of Things) are suitable development applications whose prototyping can be done in no time using graphical language G-Language. The compatibility of LabVIEW software with Microsoft, RTOS like LINUX is an added advantage.

For sophisticated measurement and tests and system development LabVIEW provides easy environment where respective blocks are imported and connected through wires in both parallel and serial. Connecting nodes through wires enables variables to propagate and transfer data. The parallel programming is possible here by which system performance can be tested and the scheduling of jobs for online and offline processing helps processor to work on data constantly and synchronize between processes for multithreading and

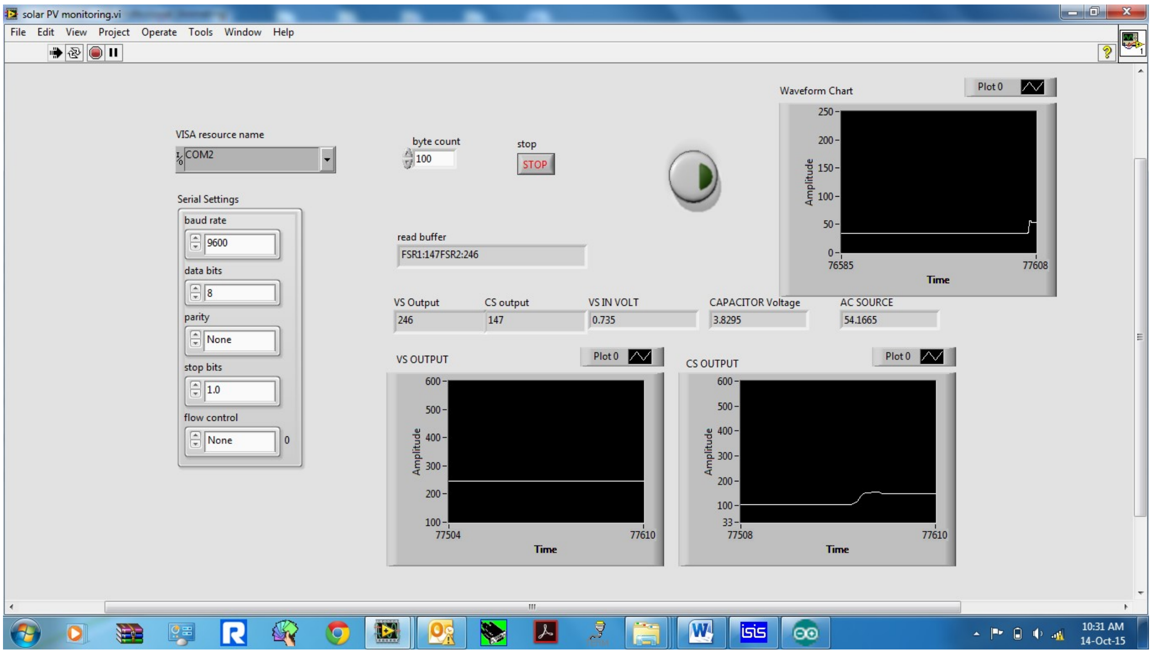

Figure 4.12: LabVIEW Model

multiprocessing by a built-in-scheduler available in LabVIEW.

The Graphical User Interface of LabVIEW provides panels for user application development namely user interface or front panel. The virtual instruments has three components as block Diagram, front Panel and a connector Panel. Connector panel can be called in other VI models. Front Panel has Control and indicators. The response is shown by indicators which is given input from Control. The overall block diagram is part of back panel where graphical design of source code exists. Objects can be seen on both front and back Panel which also has provision of structural programming and function declaration as part of function palette. In LabVIEW every resource can be referred as node that is control, structures, functions and indicators are nodes which are connected by wires and Indicator node displays the operation result of previous control nodes.

The VI runs the final design considering it as a program in Front panel or as node in block diagram. The structural programming helps to bind a set of subprograms in a large program. The ease availability of defined blocks in LabVIEW helps to drag and drop respective units, connect graphically is especially liked by non-programmers. The tutorials and help documents make usage simple to create small applications. The scope of becoming expertise in high-quality G programming is always preferred. The knowledge on syntax, hierarchy, workflow will help user to solve complex algorithms and its implementation which operates 24x7 and for years especially in distributed computing where Server role becomes crucial for multiple Clients, can be implemented in G-language.

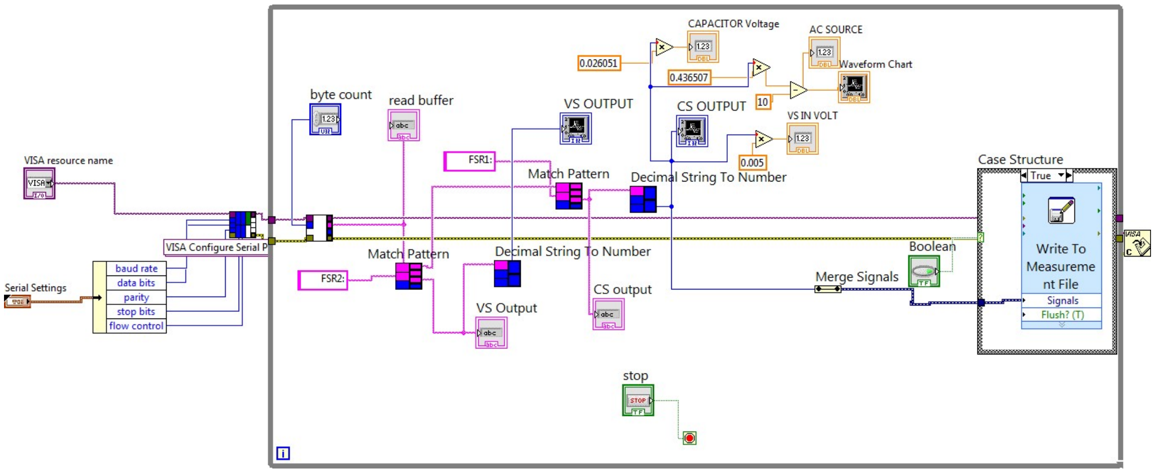

Figure 4.13: Back Panel of LabVIEW Model

A sample LabVIEW environment is as shown in Fig. 4.12 which has various panels including display, start and stop knobs for input and output analysis. Based on waveforms results are analyzed for error. Virtual Serial Port can link to Proteus with LabVIEW. Fig. 4.13 shows the back panel of LabVIEW.

4.7 REAL TIME DATA MONITORING IMPLEMENTATION IN SMALL GRID WITH VIRTUINO APP:

Data monitoring is foremost need of any system to have a contentious and regular check on the operational parameters. This data not only provides the information about the healthiness of system, but also provides the guidelines for the operator for the actions to be taken or any future possible breakdown / uncertainty. The above developed data monitoring system is described which is capable of collecting data from remote stations with the help of LAN Network through which data is transmitted to the server room through GSM. A prototype for the system is developed and results shows system is energy efficient and reliable.

Fig. 4.14 shows the block diagram of the Arduino UNO, NodeMCU and its associated external devices like LCD, relay with driver and digital voltage sensors. It comprises of +12V/500mA power supply, NodeMCU, Liquid crystal display (LCD), relay control system, power sources, digital voltage sensors . The main objective to show the system is to display the status of power sources (PS1, PS2,.) availability using digital and switch to the power source accordingly. Arduino UNO and NodeMCU/Wi-Fi modem are connected serially. NodeMCU/Wi-Fi modem transferred the sensory data packet to cloud using Wi-Fi

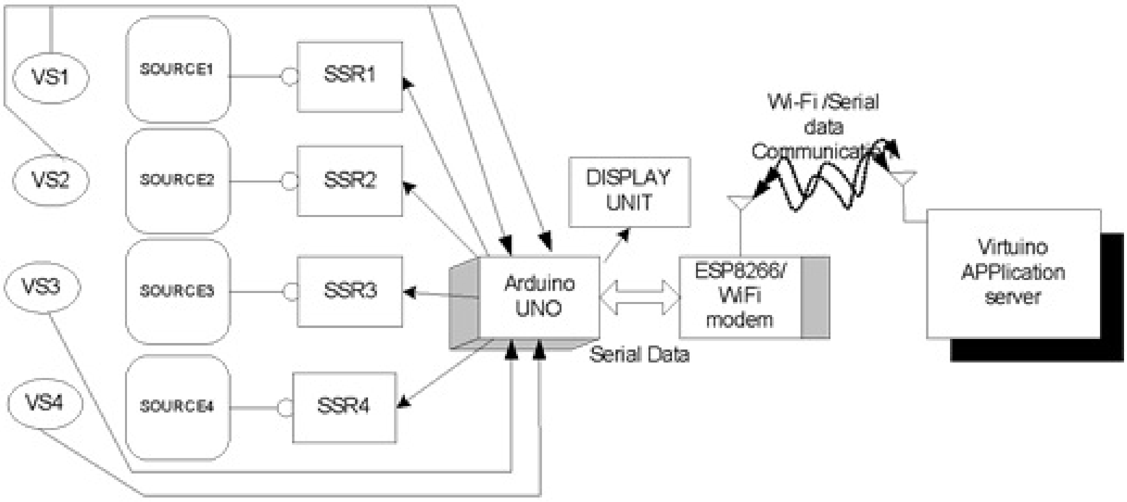

Figure 4.14: Block diagram of power source shifting system

link to Firebase server or VIRTUINO APP to know the status of power source and switch the state of one to another source.

4.7.1 SIMULATION MODEL AND CIRCUITS

The following are the interfacing connections of Arduino UNO, NodeMCU/ESP8266, SSR, LCD and the voltage sensors.

1. +5V and GND pins of NodeMCU and Arduino Uno are connected to +5V and GND pins of power supply.
2. Pin 1 and pin 16 of LCD is connected to GND of power supply.
3. Pin 2 and pin 15 of LCD is connected to +5V of power supply.
4. Fixed legs of 10K POT is connected to +5V and GND of power supply and Variable leg to pin3 of LCD.
5. Pin 13, GND and pin 12 of Arduino LilyPad is connected to pin 4 (RS), pin 5(RW) and pin 6(E) of LCD
6. Pin 11, pin 10, pin 9 and pin 8 of Arduino LilyPad is connected to pin 11 (D4), pin 12(D5), pin 13 (D6) and pin 14(D7) of LCD
7. +Vcc, GND and OUT pins of Digital voltage sensor are connected to +5V, GND and A0 pins of Arduino UNO
8. +Vcc, GND and OUT pins of Digital voltage sensor2 are connected to +5V, GND and A1 pins of Arduino UNO

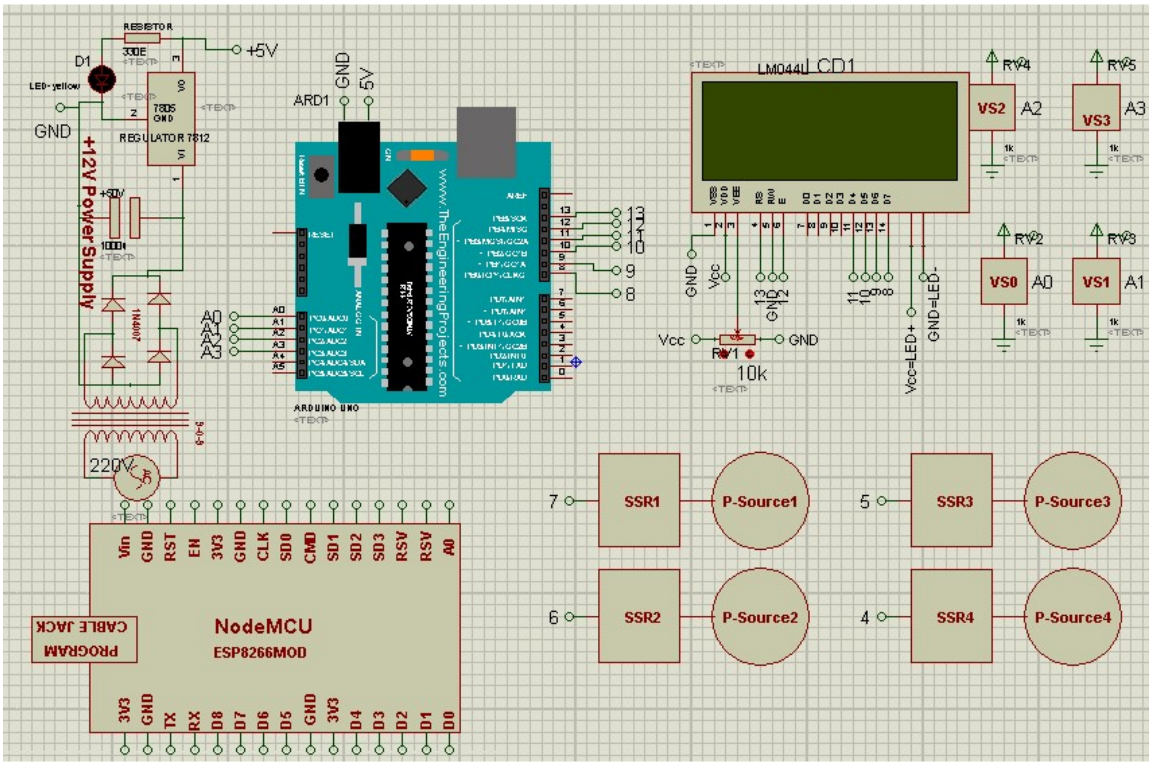

Figure 4.15: Circuit simulation

9. +Vcc, GND and OUT pins of Digital voltage sensor3 are connected to +5V, GND and A2 pins of Arduino UNO

10. +Vcc, GND and OUT pins of Digital voltage sensor4 are connected to +5V, GND and A3 pins of Arduino UNO

11. Input of relays are connected to pin7, pin6, pin5 and pin4 of Arduino UNO.

12. TX pin (7) of Arduino UNO is connected to RX pin(D6) of NodeMCU

Fig. 4.15 and Fig. 4.16 are showing the simulation model of system for Selection of suitable power sources like wind power source (PS1), solar power source(PS2), hydropower power source(PS3), and inverter power source(PS4) output. Solid state relays (SSRs) are using to changeover the power sources one to another. The voltage sensors like VS1, VS2, VS3 and VS4 are used to check the availability of power source available.

Fig. 4.17 and Fig. 4.18 are showing the connections among various devices to switch the source for Selection of suitable power sources like wind power source (PS1), solar power source(PS2), hydropower power source(PS3), and inverter power source(PS4) output. Solid state relays (SSRs) are using to changeover the power sources one to another. The voltage sensors like VS1, VS2, VS3 and VS4 are used to check the availability of power source available.

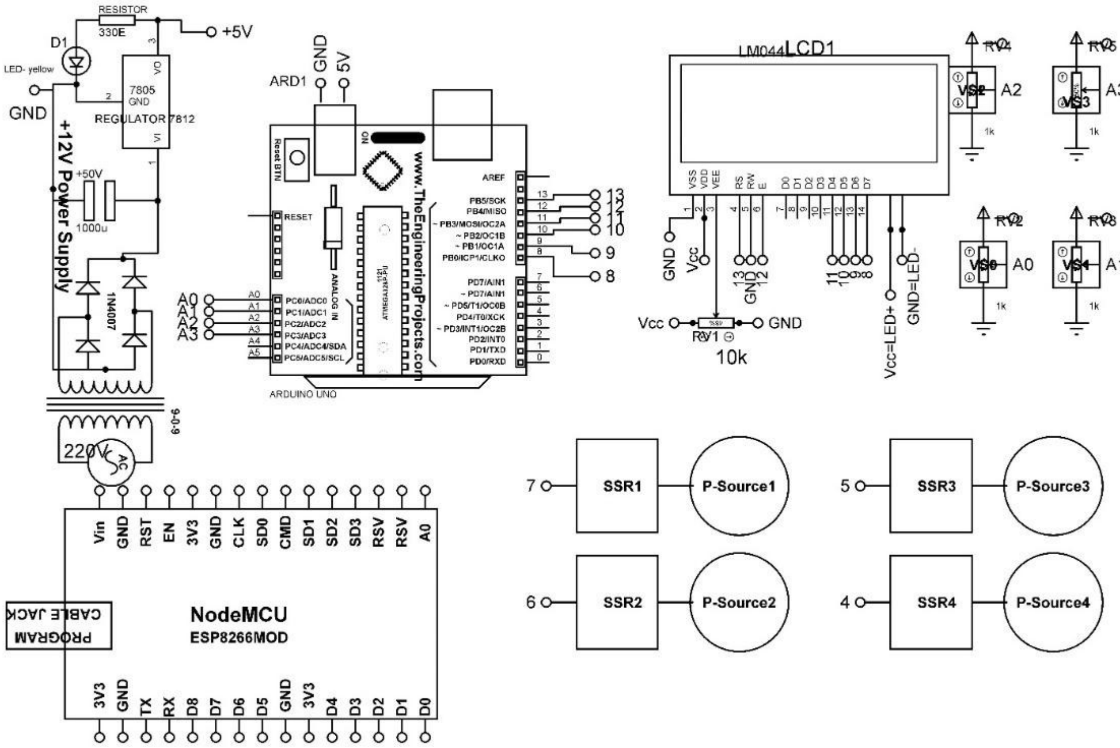

Figure 4.16: Circuit simulation of Solid State Relay (SSR)

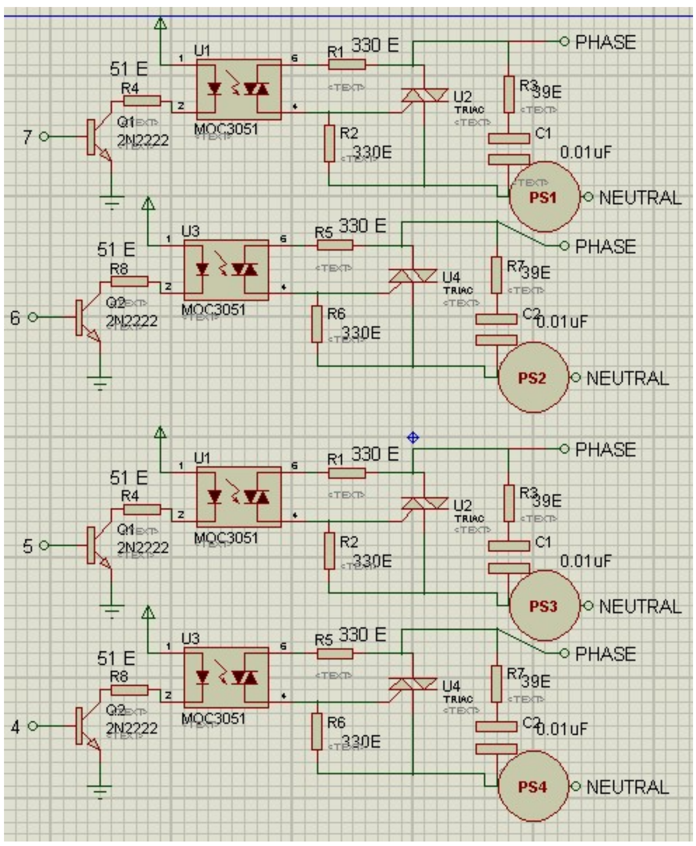

Figure 4.17: Circuit diagram

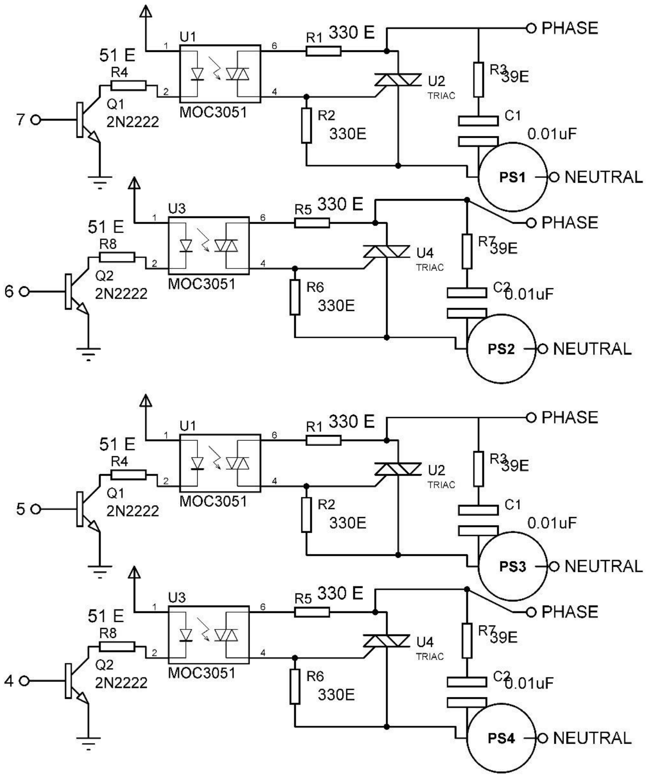

Figure 4.18: Circuit diagram of Solid State Relay (SSR)

4.7.2 VIRTUINO APP

Virtuino application is human machine interface platform on cloud. Virtuino application is controlled through Bluetooth, Wi-Fi, GPRS and ThingSpeak. It is freely published application given by Ilias Lamprou.

STEP.1 Make connection among Arduino uno, NodeMCU and external devices

STEP.2 Follow the following step

(a) Click to download the Virtuino Library ver 1.1

(b) Run to add the library via Arduino IDE.

(c) Burn the hex code in NodeMCU

STEP.3 add Wi-Fi settings with android device

STEP.4 Make the Application in Virtuino app and run it to interact with ESP8266/NodeMCU

We use a graphic interface that enables different elements to be joined together to provide the required flow. The final display of the remotely located power system shall be as shown in Fig.4.19 and Fig.4.20 on the operator's console.

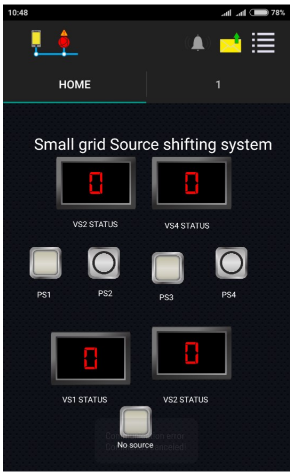

Figure 4.19: Virtuino application on server

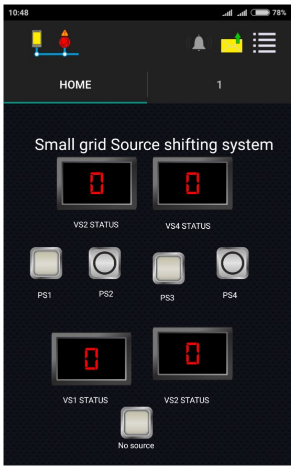

Figure 4.20: Virtuino application on server

4.8 RESULTS:

With the help of the fundamental circuits, the operating parameters of the remotely located power plants were measured. These parameters were converted in to digital form with the help of Data Acquisition Card. The data in to the digital form was communicated to ZigBee based WLAN. With the help of ZigBee, the data pertaining to remotely located power systems was communicated to GSM network, where it is available. The distance between the remotely located power system and the GSM location can be long enough, that, it is out of ZigBees communication range. In this case it is required to form a network of ZigBee Coordinator. Based on the distance, the number of ZigBee coordinators will increase and it will increase the complexity of problem. With the help of newly developed algorithm, as mentioned in chapter 3, the numbers of ZigBees required are minimized. With the help of hardware developed as discussed in chapter 4, a network of ZigBees was created so that that, the data can be communicated effectively from remote location to the desired location. Microcontroller based Arduino UNO were used for developing hardware for the ZigBee network and then to communicate from ZigBee to GSM network. With the help of Proteus Software codes were written for the Arduino UNO. The final data was communicated with the help of GSM (WAN) and data was received at final control room. With the help of LabView secondary data was received from the GSM to Operators console. With the help of Virtuno App, the final data was displayed at the operators console to take the requisite action. The display results shows that the parameters measures at the remotely located site are same as displayed on the operators console. Thus with the help of hardware, LWAN, optimization techniques, a real time data monitoring system was developed for the remotely located systems.

4.9 CHAPTER SUMMARY

In this chapter the detailed description of hardware is represented. For the purpose of demonstration two remotely located power systems has been considered for data monitoring. Whereas one is within the vicinity of communication and other is not in the vicinity of communication. The hardware has been developed for data sensing, Signal processing, data communication, the transmitter, receiver model for both GSM based and Localized WAN based models. The Chapter also describes the various software packages used and coding for the same. The data finally received at the control center has been displayed in user friendly format. The data logger and server can keep a record of all relevant data received.

Thus, the research work presented in Chapter 3 and Chapter 4 demonstrated that, with the help of the suggested methodology in the research work, can be adopted and applied to monitor the performance of the remotely located system for the control center.

The result of this research work and conclusion are summarized in Chapter 5.

CHAPTER 5

CONCLUSION AND FUTURE SCOPE

5.1 CONCLUSION

The main contribution of this research work is to develop a methodology for monitoring the performance of remotely located power systems from a central location. As electricity plays a vital role in improving the livelihood of human being and closely related to many important and essential aspects of human life such as education, health, information, etc. Inability to access electricity adversely affects the livelihood of a person. Therefore, basic idea is to improve the livelihood of the villagers by providing them a regular power supply and rectify immediately if any breakdown occurs. In this context, Chapter 1 discusses the various aspects and challenges that many villages could not be electrified so far. However, many efforts have been done with the help of renewable energy to meet the electrical demand of these villages, in spite of which there is deficiency of reliable electric supply.
To execute the work and understand the apply the present available technologies, literature survey is covered in chapter 2. From this survey it can be concluded that there are various methodologies available for different application such as micro Power plants, data sensing, real time data monitoring, path optimization etc. But there is no such work which integrates all these technologies and monitors power plant parameters centrally. Hence, It is required to develop a single integrated system for the remote monitoring of power plants with integration of various technologies and path optimization over Earth‘s surface.
Thus optimization and development of hardware circuitry with integration of communication technologies with the help of short-range communication devices is carried out in proposed research work. The work is executed with collaboration of hardware circuitry and software coding with optimization used as mathematical tool such as MATLAB.
In Chapter 3, use of optimization to minimize the number of short range communication devices for a WLAN is described. With the help of newly developed algorithm (as described in Chapter 3), it is possible to optimize and minimize the required numbers of Geo coordinates (locations) for the purpose of data communication. In this work the algorithm is developed and also applied to a case study. The case study proposes to electrify four villages with the help of renewable energy power plants. The operating data of these four power plants, which are remotely and distinctly located villages, were communicated to

the requisite location (where GSM network is available). The result of case study is indicated in Table 3.14 shows that with just four intermittent communicable devices, the operating parameters of all the power plants can be communicated globally.
The algorithm, which is developed and demonstrated in this work, uses Haversine formula to identify the set of Geo coordinates on the earth's surface. One digit variation at 5th decimal place in coordinates causes an error of '6' meters on the Earth's surface. Hence, for the more accurate estimation of GPS coordinates, the optimization is proposed to increment by 0.00001. Due to this small increment and with multiple locations, the time required for the identifying the GPS locations is very large. In this research work, for the described case study, to calculate the set of Geo coordinated over 1 km (only) the computing time with MATLAB R2014a and Intel's latest i5 machine it took approximately 4 hours. However, with advancement in chip processing speed, in future, the computation time may be reduced.
To verify the integration of short range communication devices (WLAN) with WAN, a prototype hardware model was developed and tested at the laboratory level. The results shown in Chapter 4, clearly shows that, with the help of hardware circuitry and various software tools, the operating parameters of remotely located system are communicated and displayed at the operators console at the centralized location on real time basis.
The research clearly demonstrates that the modern technology and renewable energy can reduce 'distance' between remotely located villages and 'popular' locations like cities that can really help the underprivileged society to be the part of mainstream society. Additionally, the research work also provides an optimized solution for this noble cause, that not only helps in reducing initial investment but also reduces the complexity, and thus reduces the operational and maintenance, and also improves the system reliability.
In addition to the above, the remote locations face extreme 'environmental conditions' like very low temperature, heavy rainfall, snow falls, heavy summer etc. The designed electronic hardware must be able to withstand these extreme conditions- especially in, low temperature, snowfall the electrical battery perform very poorly and drains rapidly. Hence, in case of extreme conditions the initial investment cost may increase.
In nutshell, this research work is an attempt to help the underprivileged society and help in nation building.

5.2 FUTURE SCOPE OF THE WORK:

In any research work further improvement is evident. Therefore, some suggestions are listed here as a part of future scope of the work. This work, it is considered only for remotely located villages, which can be adapted in developing smart villages. But this idea is not limited to the villages. This can also be extended further; such as defense services, animal movement in forest, disaster management etc. With the help of algorithm, the defense services can identify the Geo coordinates of all the locations over a specified distance and also help in identifying enemies entering through these Geo coordinates. The said algorithm can also be used to identify enemy guns and tanks. Additionally, Air force can identify the set of locations over a specified distance. As the algorithm gives the set of coordinated over a specified distance, forest management services can use this algorithm to identify the set of geo locations to install animal tracking mechanism. During the natural calamities in assisting disaster management team it can be very useful tool.

From the above discussion and the future scope of it we can easily conclude that this research will greatly help us in elevating the poor and under priviliged groups living in the remote and non attended parts of India. (By helping these communities, we can ultimately help in overall development of the nation.)

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