

# **CHAPTER-1**

## **INTRODUCTION**

In this Chapter, introduction to the automation, wireless sensor network, linear/ nonlinear control system and communication media are discussed. Chapter also includes the complete outline of the thesis. The main focus of the chapter is to discuss the background of the ‘smart home’, the enhancement in technologies in the past century and improvement of the living comfort of the human being with less power consumption.

### **1.1 Power Generation and Consumption Scenario in India**

India is amongst the top six countries in the field of electricity generation and produces about 4% of world’s total electricity. India ranks sixth in terms of electricity consumption and consumes around 3.5% of total world’s electricity, although it is very less as compared to developed countries. United States is the biggest consumer followed by China and Russia. In the last decade, electricity consumption has increased by 64%, due to rapid population growth and automation. Power shortage has become a problem for developing and developed countries. India is facing a power shortage of around 70,000 MW [<http://www.saveenergy.co.in>]. According to one survey by world bank, it is estimated that the investment in electricity generation would increase by \$4 trillion in the next 30 years

The big issue to address is power shortage. There can be two approaches to meet the requirement of electricity. One is to produce more electricity by deploying more conventional and renewable sources of energy. Other approach is the more efficient and optimized use of available electricity by making domestic appliances smart. Both the approaches are equally important and need to explore, although this thesis is focused on the later approach. The smart devices should not only consume less power, but also help to minimize the power wastage.

To fulfill the power requirements a lot of efforts are made by the government. As per the records of ministry of power of India there was a growth in power generation by 6.6% for year 2009-10, for the year 2010-11 it was 5.56%, year 2011-12 shows 8.11% growth, 2012-13 has 4.01%, 2013-14 with 6.04% and

2014-15 growth by 8.43% [<http://powermin.nic.in>]. For achieving this fast growth a lot of natural resources are deployed. The overall generation is increased from 967.150 BU in year 2013-14 to 1048.673BU in the year 2014-15, which involves thermal, hydro and nuclear energy [1]. The pace for use of natural resources opted to achieve power generation is so fast that soon all the resources will be vanished. To target these issues power sector has become the prime area for research and development for the researchers. Not only the power generation, but also its efficient use is prime issue. So with the vision of providing affordable quality power, R & D in power sector has two goals. First is for manufacturing industries in the terms of electrical equipment for generation/transmission and distribution of power. Second goal is to improve the efficiency and effectiveness of various technologies. To achieve these goals automation should be in the position of adapting new approaches with minimum loss. For the power sector a committee was created and ACT 2001 was constituted by MOP under the chairmanship of CEA to prepare R & D for next 15years. The focus was to raise fund and to ensure the outcomes of research would be beneficial for customers.

In the year 2003 Electricity ACT was constituted by the Central Electricity Regulatory Commission (CERC). The main focus of commission was to bridge the gap between demand and supply. In 2004, a research activities energy technology center was established to integrate the resources with technology and to convert it into deployable form. In 2009 NETRA [<http://powermin.nic.in>] was established and the focus area includes the waste management, efficiency improvement and cost reduction.

A lot of efforts had been put by the government to provide required power to customers. As an academician or researcher one has the responsibility to make oneself and others aware of utilizing power more effectively and efficiently, to avoid wastage of power due to laziness of human being. For this a lot of approaches had been made with advancements of technology. One of the approaches is to focus on the efficient household uses of power. In household uses lot of power is waste due to lack of knowledge about exact suitable environmental

parameters. For example the standard light intensity value for the living room is 300 lux and to perform any task it is 500lux. For family room/home theater it is 300 lux, for performing task it is 500 lux and to watch TV it is 150 lux only. For children bedroom general intensity of light required is 500 lux and if task is to perform it is 800 lux. For adult bedroom general is 300 lux and for performing task it is 500 lux [ergonomics.about.com]. All these values are standard and generally not known to general people. Similarly [www.ohserp.org.au] describes the environmental parameters like temperature and humidity which are dependent on each other. The comfort levels for human beings have different values. In summer with light clothes, if relative humidity is 30% then the comfort temperature value is 24.4<sup>0</sup>C to 28<sup>0</sup>C and if humidity is 60% then this value drops to 23<sup>0</sup>C to 25.5<sup>0</sup>C. In the winters with warm cloths, if relative humidity is 30% then comfort temperature value is 20.5 to 25.5<sup>0</sup>C and if humidity is 60% then this value drops to 20 to 24<sup>0</sup>C. If these values would be known to people, then it would be helpful to utilize power efficiently.

In the approach to achieve efficiency if a system is developed, which could sense the environment and display values on screen and also could control the ambient room conditions with power saving, it would be of great help. A generic algorithm which could be capable to handle the dimming level of appliances with minimum power consumption would be a new approach to use power efficiently and effectively.

## **1.2 History of Home Automation**

The new era of technology has a prominent impact on ‘smart home’. It can be defined as a living place equipped with intelligent appliances with comfort, security and ease to use. The concept is to fill the gap between conventional systems and intelligent systems. Lot of ideas and inventions are carried out by the researchers for ‘smart homes’ which focusses on the technical possibilities. The aim of the research in this field is to emerge phenomenon of smart home with reliability of product and comfortability of user. The introduction of information

technology opened a platform for possibilities to make appliances more user friendly and intelligent. Here Intelligent means the capability to learn and act accordingly with minimum energy consumption.

The last century had seen a dramatic revolution in technology. Literature shows, in the early 20<sup>th</sup> century during the year 1915-20, for the first time electricity based household machines were introduced. These machines turned out a great help to the ladies, but the problem was not having appropriate household electricity supply to use these appliances. After that during 1920-40 concept of household appliances grew up. People understood the importance of electricity and agreed to pay additional amount. During 1940-59 women started looking for job outside the house, for financial support to the family. During this period women realized the importance of time management between home and office and they opted for machines more rapidly and comfortably. In 1960-90 new appliances were introduced, new styled kitchen were proposed. Sale of television and recorders had increased. Cordless and mobile phones were introduced. Use of internet became common to the people with Personal Computers at home [2].

After 1990s a revolution in technology happened in the form of laptops, tablets, Wi-Fi, 3G, 4G and internet of things etc. Now the world is just a click away. With the revolution in technology, per family capital has also increased as male and female are now equally competent. Today everyone wants everything get done with ease at home. Due to lack of time and high capital income, people are moving towards more comfortable home automation systems. Now the time is not only for the semiautonomous appliances, instead people's choice is diverted towards fully autonomous systems.

Home Automation and smart homes are synonyms which refer to the convenient control for home appliances including telecommunication, security, lightning, heating, cooling etc. The other challenge is the requirement of remote control for the systems in the form of a small embedded device, a mobile phone or a laptop.

Though the ‘smart home’ concept is equipped with advance technology, the uptake is slow as compared to other rapid technologies. The barriers to uptake are- high initial investment, renovation of house is much costlier than building a new one, prior training required and on top of these is the lack of common protocol for controlling more than one appliance. The solution must be in the form of generic algorithm compatible for most of the appliances with ease of use, flexibility and reliability [2].

Although information technology is being used with potential but still migration of it from research place to home is a big challenge. The main reason for it is, presence of not only the young people who are familiar with technology, it also comprises of elderly people and children. Till date smart homes are established only for technology push by the suppliers, but very less attention is towards the exact need of consumer.

To make the house intelligent different approaches have been taken. One of the approaches is learning capability of the systems based on fuzzy logic and artificial intelligence. In these technologies, the system learn the usage of appliances and shift its functionality accordingly. But dependency on fuzzy logic makes it complicated.

There are a lot of definitions for smart home but it still remains undefined. It may be the system which is wearable, portable or implantable. The system should perform without human intervention. It could be defined as the system with intelligence or decision supportive. But when intelligence comes into the role, question arises which type of intelligence it should have. A lot of experiments and test beds have been developed for testing the features and criteria for the smart home. Building automation concerned with improving the indoor habitat with comfort. Other than the technology, monitoring and managing power consumption with user interface is another area to focus. Minimizing the power wastage, by the smart devices is also a recent area to research.

### **1.3 Role of Control System in Automation**

A building is similar to a system with a number of physical parameters depending on each other and with the environment. It is observed as subsystems showing linear or non-linear dynamic behaviors. Complexity in the control operation increases with the changes in internal and environmental behaviors in a building. Due to the increase of environmental concerns, control system plays a vital role in the reduction of power consumption without affecting comfort goals.

Due to the increasing demand for energy savings, control on comfort level of the systems is continuously evolving process.

To fulfill the requirements of energy efficiency and comfort, an optimal solution is required not only to reach a good performance, but also to be accepted by the end-user. It is difficult to define exactly what is needed and priorities of the occupant, within the limits of comfort. Depending on conditions a system has some performance parameters [3]. Some of the parameters are as follows.

- Performance and comfort
- Effective Cost
- Ease of use
- Maintenance
- Flexibility
- System stability
- Systems integration

The interconnection of components to design a desired output is a control system. In other words control system is set of commands to regulate the behavior of device. The control may be open loop or closed loop.

Open loop control shows the actual behavior of the system as per input signal however closed loop system is used for desired output with different input signals. Open loop systems are simple to implement, convenient, free from problem of stability and easy maintenance. But these are unreliable, inaccurate and are difficult to sense the changes in the external environmental. To overcome these limitations of open loop, closed loop are used.

In closed loop systems parameters are controlled by generating error signal from the difference of required value and input value of signal. The system behaves according to the generated error signal.

The literature suggests, for controlling these error signals PID controller is one of the efficient methods. PID controller includes Proportional, Integral and Derivative terms to control the system accurately. It is used to calculate the best parameters for PID controller, like  $K_p$ ,  $K_i$ ,  $K_d$  and due to its simple structure, it is widely used in control industries.

To achieve the stability and desired control response, tuning methods are used. Tuning the PID parameters is a difficult problem, as every system has different behavior.

There are various methods available for tuning the PID controller for e.g. Manual tuning method [4] is used for parameters adjustment, by watching the system responses.  $K_p$ ,  $K_i$ ,  $K_d$  are changed manually, until required system response is obtained.

Ziegler–Nichols tuning method [5] was introduced in 1940s by John G. Ziegler and Nathaniel B. Nichols. This method is based on experiments executed on an developed control loop (a real system or a simulated system).

PID tuning software methods are some software which can easily calculate the gain parameter. E.g. MATLAB Simulink PID Controller Tuning and BESTune, Exper Tune etc.

To tune the parameters  $K_p$ ,  $K_i$ ,  $K_d$  researchers also has opted for some optimization algorithms like Genetic algorithm and Particle Swarm Optimization. Hadi Ramezani et. al compares the existing techniques for controller tuning with PID using PSO [6]. K. Latha et. al focuses on simulation model for PID controller using PSO [7]. S. Ravi et. al includes simulation of GA based temperature control system [8].



#### **1.4 Background of Communication Media Used in Automation**

Less energy consumption and comfort with ease to use are prime factors for technology used in the smart homes. Remote control based systems are having advantages as these are easy to use, also people can operate these systems remotely.

For the remote control, communication media is the most important factor. Internet is a good media, but it is crowded with other applications, and also requires a lot of resources and efforts to make it secure and reliable.

Other media is mobile phones, which provides a wide range of operation and supports services like SMS and voice commands. But it needs services like GSM, CDMA and protocols like GPRS, EDGE etc. In this case security is better but, has higher service cost. These methods are useful for controlling the system from global distance.

For short range control, as for controlling the systems within the home the literature has proposed different approach. Conventionally wired control was used, which is complicated and clumsy. Power line carrier system is used for sending coded signals to programmable switches through existing wires in the house. X10 is well known protocol for power line carrier systems [2]. X10 is a protocol which uses the power line bandwidth and doesn't have interference to existing power signals. It can be operated through computer or remote control with frequency of 120 KHz. A generic module is interfaced between appliance and module. Upto 256 appliances can be controlled through single X10 controller. Every appliance has a unique address. For performing a defined task, commands are sent to that particular address only.

Insteon is the other protocol, used for digital communication between smart devices through normal electric wires [2]. Insteon is a dual band mesh topology with A.C power and RF protocol. It was invented by Smart Labs, Inc. Using Insteon protocol each device can receive or transmit the message without the need of master node.

To avoid the complexity of wired control, wireless control comes into role. For wireless control different modems are available. Initially IR based remote control were introduced. Infrared (IR) remote control is a low cost solution for the electronic devices like fan, air condition, heating system. Infrared remote control is based on invisible light pulses with the visible wavelength spectrum (approx. 950nm). Line of sight is required between the transmitter and the receiver, any obstacles between prevents from reception.

But the limitations of line of sight are observed for infrared light as the medium. To overcome this limitation, during recent years there is a trend for radio frequency (RF) based remote controls. Mohammad Noshad et. al concludes the communication module used for communication and discusses the limitations of IR communication [9].

Another challenge is to lower down the power consumption by remote control in idle condition. Security is another issue, depending on the application a secure link is required to avoid the misuse of the device.

Radio frequency communication is based on the electromagnetic waves as transmission medium. RF propagation properties provide high distances and passes through non-shielding materials upto some extent. RF module is license free and operates on IEEE802.15.4 standard. For remote control operates on ISM band which are the license-free bands. ISM band includes 802 family standards with 802.15.1 bluetooth, 802.11 WLAN and 802.15.4e. RF module Zigbee falls in ISM 2.4 GHz band. For Region 1 (Europe, Africa, and former Soviet Union) the frequency band is 434 MHz, for North and South America is 902-928 MHz, in Europe the SRD-band 868 MHz and in the US the frequency band is 315 MHz for remote controls. World-wide compatibility is ISM-band at 2.4 GHz. In India ISM frequency band for RF module is 433MHz and 2.4 GHz. The payload data needs to be modulated on the RF carrier with amplitude Shift Keying (ASK) and Frequency Shift Keying (FSK). Table 1.1 shows the clear difference between IR and RF communication media.

Table-1.1 Comparison between IR and RF communication media [10]

Parameters	Infrared	Radio Frequency
Power consumption	20 - 150 mA	5 -20 mA
Power consumption (stand-by)	Depending on microcontroller idle current (<1 $\mu$ A)	
Range	Up to 10 m	Up to 100 m
Bi-directional option	No	Yes
Bit-length of frame	40 bit per frame	80 - 140 bit
Data rate	500 bit/s - 1 kbit/s	Up to 100 kbit/s
Line of sight	Required	Not required

Due to benefits of RF module on IR module, it is preferred. Depending on the application a vast range of RF modules are available in the market. Table 1.2 is for the comparison of different RF modules.

Table-1.2 Comparison for different wireless RF modules [sunrom.com]

Features	RF module nRF24L01	RF module 433 MHz	ZigBee	Wi-Fi	Bluetooth
Range	1100 m	100 m	10-100 m	Upto 100 m	10 m
Data rate	250kbps, 1&2 Mbps	300 bps – 3 kbps	20, 40, 250 kbps	11 & 54 Mbps	1 Mbps
Frequency	2.4 GHz	433 MHz	2.4 GHz	2.4 & 5GHz	2.4 GHz
Power Consumption	Ultra low	Very low	Very low	High	Low
Modulation	GFSK	ASK	BPSK	QPSK	$\Pi/4$ DQPSK
Standard	IEEE 802.15.4	IEEE 802.15.4	IEEE 802.15.4	IEEE 802.11,a,b,g	IEEE 802.15.1

Topology	Ad-hoc, Mesh, Star, Tree	Ad-hoc, Mesh, Star, Tree	Ad-hoc, Mesh, Star, Tree	Ad-hoc, Point to point, Star	Ad-hoc, Point to point, Star
Cost	Less	Very less	Less	High	High

On the basis of characteristics and system requirement Zigbee protocol is a good option to develop a communication link between two sections. The ZigBee standard can address up to 65535 nodes in a single network. Zigbee protocol is capable of handling of a large scale wireless sensor network, which can monitor or control number of applications.

### **1.5 Role of Wireless Sensor Network in Automation**

Wireless Sensor Network (WSN) is a fast growing research area. It comprises of sensor nodes which are capable of communicating with each other and to a main server. The main challenges to establish WSN are energy efficiency, adaptation, robustness, responsiveness and security. But the beauty of WSN is its capability to accommodate a large number of sensor nodes. These nodes can be deployed on remote areas and information is passed on by hopping between nodes.

Hardware component for nodes comprises of processing unit with small memory capacity, sensing unit and communicating unit. Here communicating unit has radio frequency operated modules, having some coverage range. Nodes are deployed such that they can cover maximum area. The nodes are low cost embedded systems and less complex than conventional wired networks. These are able to communicate with all peer nodes in mesh topology.

Programming is also an aspect of WSN nodes designing, which includes the knowledge of, type of sensor and its operating protocol. Mainly two types of application requirements are identified, static and dynamic. In the static type all design requirements are identified before its deployment, hence it can be observed that there is no change in features from the sensors during its lifetime. On the

other hand the dynamic type deals with the undefined future events, and its behavior depends on the changes in surrounding environment. The principal of reconfiguring sensor software during life time is referred to adaption.

WSN is capable of gathering the information from environment, process it and communicate it in harsh conditions also. The sensed data can be used for decision making to take action. In the recent advances in technology, WSN is used in sensing and reacting systems for agricultural use, army uses and Industrial purposes.

This technology can play a major role in home automation. A number of home appliances can be controlled with the same network and message can be passed easily. Also it is secure and flexible. Zhen-ya Liu et. al discusses the environment parameters monitoring with Zigbee [11].

## **1.6 Research Background**

Referring to the various publications in reputed international journals, papers are reviewed (detailed description in chapter 2). The literature focuses on minimizing the power consumption by dimming of appliances. Also with use of optimization algorithms like genetic algorithm and particle swarm optimization algorithms, power consumption can be reduced to a significant level.

The existing system does not have any indicator or display to show the ambient conditions, as a result it is difficult to optimize the level control of the device.

In this research work an intelligent remote control is developed which displays the physical parameters of room and trigger the voltage level to desire value and ambient condition of room is maintained. This ensures not only the efficient use of the power but also ensures the lower cost and ease of use. The system is simple and flexible. It operates on 2.4 GHz RF frequency, which is available as free band in India and requires no line of sight to operate.

## **1.7 Research Gap and Motivation for the Research**

On the basis of literature survey, the research objectives are identified from the research gap in the literature. Following points are concluded-

- Limitation with previous art is considered and a new approach to control home appliances with low cost intelligent hybrid remote control is proposed.
- Universal algorithm to control the multiple appliances is also a new method to overcome the limitation of previous art.
- Communication media used in this research work is RF module.

## **1.8 Objectives**

Objectives for the present research are concluded as follows-

- Design a system to observe performance of home appliances.
- To implement a generic optimization algorithm to control the dimming levels of appliances.
- Performance analysis of the system by simulation of the designed system.
- To design a hybrid RF remote control.
- Hardware implementation of the system.

## **1.9 Thesis Organization**

The Thesis is divided into eight chapters, according to the need of description of research work step by step so as to make the concept and results clear.

Chapter 1 is about introducing the key words of designed system including wireless sensor network, home automation and control system. Objectives are concluded on the basis of research gap from prior art and motivation for the need of research.

Chapter 2 is the literature review, a sufficient review has been carried out to describe the existing art, by referring various research papers published in reputed journals. It includes the conclusion from existing art.

Chapter 3 explains the complete description of the working of the system with the help of block diagrams and circuit diagrams for both the sections (remote control and receiver section). Brief description of all the components used is also included in the chapter. Proteus simulation models are designed to check the feasibility of the circuit operation.

Chapter 4 describes the complete methodology to develop the system and the calibration of sensors used to develop the system. The dimming methodology of the appliances with respect to firing angle and their power consumption is discussed in detail. The calibrated sensors are tested with the standard instruments and results shows accurate calibration.

Chapter 5 explains the stepwise process of firmware development, which includes the transfer functions for home appliances (heater, bulb, exhaust fan) and the sensors used. Implementation of PID with GA and PSO and its programming Flow charts are also explained. This chapter also describes the steps followed to develop firmware for the system. It includes mathematical models of appliances, their simulation and programming to microcontroller.

Chapter 6 concludes all the results which shows the power consumption by home appliances (heater, bulb, exhaust fan) using PID, GA-PID and PSO-PID and concludes PSO-PID is best suited algorithm to control the environmental parameters (temperature, humidity and light intensity) at desired level. Cost analysis shows it is a cost effective solution for the smart homes. Current consumption analysis proves it is an energy efficient solution for home automation, as compared to the already existing systems.

Chapter 7 includes major outcomes with conclusion and future scope of the system. The chapter also discusses the novelty of the developed system.

Chapter 8 elaborates the research publications with description for the current research, for the duration of research to support and prove the validity and originality of work.

## **1.10 Chapter Summary**

This chapter gives brief introduction to keywords of the system and brief description of history. On the basis of background, Zigbee protocol for communication between receiver section and remote control is being selected, as it fulfil all the requirements of the system. The chapter includes the history and need of the 'smart home' concept. It is concluded that smart devices should not only provide the comfort and ease of use rather it should also be the energy efficient system to minimize the energy wastage. The need of a universal algorithm to control multiple appliances is also concluded. Chapter also describes the complete organization of this.