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Developing a Sustainable Green Home Automation System Model

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Abstract*: Since the advent of the first computer by Charles Babbage way back in 1822 the Computing Technology and to be precise the Information Technology has come a long way. This project deals with one such revolutionary innovation in the field of Information Technology in recent times known as the Internet of Things. The Internet of Things commonly known as the IOT is a state of the art technology of connecting our daily lifegadgetsto the internet via computer as the interfacing medium to be controlled from anywhere in the world at any time with just a click of the button over the world wide web or internet using a personal computer or any smart phone device.*

The project under concern is set to delve into the realms of this marvel of technology by developing a Home Automation Solution using IOT framework. The proposed system will consists of relevant hardware for interfacing the IOT gadgets into the computer which then can be controlled via the internet using a customized Graphical User Interface specifically developed for the system project.

The project also set to harness Solar Energy by incorporating solar panel into the system model as a renewable source for powering the entire IOT system for a sustainable Smart Green Home. Thus, the main goal of the project is to showcase the Synergistic model of Sustainable Home Automation and demonstrate how all these revolutionary concepts of Information Technology can be integrated into all in one Smart Green Home solution.

Keywords*: smart home, green house, sustainable, solar energy, automation*

1.0 Introduction

1.1 Project Background

Acquiring innovation and technological development has always been the human domain and the information technology is no different. Ever since the advent of computer technology by Charles Babbage in 1822 technological innovators and thinking minds have always strived to somehow interface with this revolutionary piece of technology which we now call it as Human Computer Interaction to harness the wealth of computing power as provided by computers.

This project deals with showcasing a revolutionary piece of concept that **information technology** has to offer in recent times, known as **IOT** technology, or **the Internet of Things,** that has taken human-computer interaction to a whole new level like never before. The very framework of the IOT technology is to open up unique technological ways and means to interface our daily technological

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gadgets with the computer enabling a user of that appliance to control it via the computer using Bluetooth technology and over the Internet or the Local Area Network or the LAN from anywhere and anytime (*Harvard Business Review, 2014).*

Until now any gadget in our usage has to be physically controlled to switch on or off thanks to the conceptual framework of IOT, things can now be controlled remotely via our very own personal computer or the PC using remote sensing technology like the Bluetooth or Wi-Fi.

The Internet of Things has made it possible to connect electronic gadgets in our daily use to the internet via an interfacing medium like a computer. Electronic gadgets are no longer isolated piece of device but in the age of social media they too have gone connected to the world wide web and can be accessed from anywhere in the world via the internet using a pc or any smart phone device (Greengard, 2015).

This project not only sets out to showcase the possibilities of the IOT technology but at the same time adds a sustainability factor into the IOT framework by the integration of Solar Power into the system model thus powering the entire system and the IOT devices using the renewable non exhaustible power of our very own sun.

1.2 Problem Definition

The project under concern basically deals with harnessing the power of IOT to make our household living easier. Maintaining a home is a major challenge in this busy and fast moving world. Thus a home automation system of some kind will not only keep the bills under check or curb any undue wastage of energy or maintaining full-fledged garden but will even look after the security of the home are some of the tasks that every household deals with every day.

In fact with a home automation system that is sustainable in nature like the integration of solar panels to power the appliances acts as a Micro Grid of its own thus not only generating sustainable renewable power but also cutting power wastage and thus controlling your grid bill.

1.3 Project Aims

Project aims can be defined as the main goal or the milestone that the project set itself to achieve. These aims can be one or multi-dimensional in its nature. The aims for the current project is one such multi-folded.

Thus the project aims are as follows:

- Developing a home automation system model both hardware and software wise to interface essential home electronic amenities such as lights, door and security cctv camera to the personal computer via serial ports interfacing to be controlled by the pc.
- Harness the power of Solar Energy using the state of the art IOT conceptual framework making the system model sustainable.
- Developing a user friendly Graphical User Interface or the GUI enabling the user to control lights, door and security cameras as part of the Smart Home Model via the pc natively as well as remotely using remote sensing technology like the Bluetooth or Wi-Fi respectively.

1.4 Objectives

The objectives of any project are sub structural to the main aims or goals of the project. The aims defines what is the ultimate goal of any project whereas objectives defines the path and ways to achieve those aims. In other words objectives acts as a blueprint or road map of what and the project aims going to be full filled from its initiation to its completion.

The following are the objectives set for the current project in hand:

- Research ways to harness solar energy.

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- Devise methods to utilize the solar power to make our homes sustainable.
- Develop computer interfacing architecture and platform for the household gadgets.
- Design intuitive Graphical User Interface system for computer peripherals handshake.
- Develop and verify software and hardware integration.

1.5 Project Scope

The scope of any project relates to the framework of its proposed functionality that the entire project lives and breathes in. The scope is in other words the functional boundary of the proposed system to be developed with which all its system features both **functional and non-functional** should reside.

The various system scope for the current project are as follows:

- Harnessing renewable solar energy and devising it for making homes sustainable.
- Using the IOT architecture as the platform to enter into the realms of solar power.
- Establishing a Micro Grid for contemporary homes making it power sustainable.
- Developing both hardware and software system for home automation.
- Designing a user friendly Graphical User Interface to control a smart home model equipped with lights, door and security camera.
- Developing Plug and Play hardware and software interfacing.
- Synchronized user experience with the system control panel and the hardware.
- Easy self-explanatory User Interface navigation.
- Modular expandable system both hardware and software wise.
- Hot swappable device compatibility with the system.

1.6 Project Risk

Risk refers to the uncertainty prevalent in any project whether big or small threatening the successful completion of the project on time. These risks could be dependent on multifactor.

The various risks involved in the current project are as follows:

- **Monetary risk**

Risk relating to the budget of the project is first and foremost the major reason for many projects not even making through its development phase even or dyeing in between its production life cycle.

- **Resource availability risk**

Availability of the required resource especially hardware components for the project proves sometimes as challenging as gathering funds or pushing a project into a senate or parliament for approval. Despite the available funds for the resource the bottlenecks do exists due to windfall reasons in the market thus impacting the project completion timeline leading to a delay and sometimes even project failures.

- **Unavailability of technical expertise**

Researching and acquiring technical expertise for the project conception and its development is yet another daunting task of any project as quality of the proposed system is at stake in absence of the required technical skills.

- **Meeting the deadlines**

Meeting the various deadlines or milestones related to the entire project development timeline in a consistent manner is a huge risk in itself where any delay of some sort can lead the entire project to jeopardy. It's a non-stop fulfillment of deadlines one after the other until the ultimate project completion deadline is met is seldom easy than said. Another threat to meeting deadlines in any project is from the valid chances of Scope Creep leading to delay in the project and not to mention any windfall event leading to the same.

- **Scope Creep**

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Scope creep as mentioned above relates to the addition of added features or requirements to the project not included at the time of project planning and conception by the project team or the client thus leading to delay or readjustment of schedule or even pumping additional funds into the project to keep up with the scope creep.

1.7 Constraints

Constraints in any project refers to the limiting factors surrounding the project whether that be in terms of budget, resource, time, availability of skilled technician or technical expertise that can be lethal to the successful completion of the project. Nevertheless the project has to be developed under these limiting factors.

The different constraints relating to the current project are as follows:

- **Budget Constraints**

Budget is a major constraint for any project whether big or small especially the bigger ones where the entire project can be implicated if necessary funds are not allocated or sanctioned for the project by the project team ending the project before it can even take off. However the challenge in the current project is to keep the budget as much as under control as the Sustainability factor of the project permits keeping the home automation needs met.

- **Resource Constraints**

Resource is yet another constraint that plague many emerging projects in-between its development phase. Thus, timely procurement of required resource both hardware and software is a great risk that any project has to deal with all the time.

- **Time Constraints**

The clock is always ticking as long as the project completion is concerned. The project team has to meet one dead line after the other in the entire SDLC of the project. Time is the constant enemy at least for the project team for meeting a host of deadlines one after the other leading to the ultimate milestone to keep the project on track. The case is not any different in the current project as well as the project requirement is both on the software side as well as the hardware with many iterations needed to develop the system as planned.

2.0 Literature review

2.1 Overview of the traditional systems

First and foremost it's worth noting that the traditional norms at homes have long been physically or manually switch the lighting or fans on or off as and when required. There was not any system where the user can switch on or off the lights or open the door or even monitor the house remotely. Thus it was more of a manual activity of controlling the lights or fans at home or any other gadgets that were operated with electricity (Stevens, 2002).

Secondly there was not much awareness towards the renewable sources of energy as most of the traditional homes were running on AC current provided by the grid by the burning of the fossil fuel polluting our environment and increasing our Carbon Footprint. As it's quite evident fossil fuels are depleting as time progresses and there will a time when none will be left for us to burn leading to great energy crisis not to mention the Global Warming attributed to burning fossil fuels (*Fedrizzi, 2008).*

2.2 Overview of a Proposed System

The project under focus proposes to research and develop a home control system model where in a home user can operate the household gadgets such as lights, door or cctv camera to name a few as included in the project for demonstration purpose via pc as well as remotely with any internet capable smart device using remote sensing technologies like Bluetooth or the Wi-Fi.

The system will also act as a model of a Micro Grid by providing the homes with its own renewable

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power supply 24 hours a day with no dangers of energy crisis using sun as a perpetual energy source for the needs of the homes. It is said that in a day sun produces that much energy in one day that would be more than sufficient to power every house on this planet for a year. Thus the world energy crisis can be solved once for all by switching to these smart renewable models of house hold living. The project proposes to incorporate the revolutionary technology of IOT or the Internet of Things system architecture to interface the various home things as mentioned above and control via the **pc as well as the internet** using **remote desktop technology**.

2.3 Synergies of Internet of Things and its Key Concepts

IOT stands for Internet of Things where by regular household appliances such as the lights, door, cctv cameras or any other electronic gadget you name it can be connected to the internet via an interfacing medium such as a pc to be able to be natively operated via the pc as well as remotely over the internet on smart devices from anywhere and at any time with just a click of a button.

The IOT technology ever since its conception has taken the technological world by storm by the sheer possibilities of this powerful technology. More and more electronic gadgets are getting connected to the internet using the framework of IOT technology. The application of Internet of Things is however varied from households to manufacturing industries from adventure toys like Drone to Space gadgets and last but not the least to Artificial Intelligence to name just a few(*Harvard Business Review,2016)*.

Thus, the Internet of Things refers to connecting devices to the pc or any especially made smart device with proper interfacing mechanism to further connecting it to the internet for remote operations. Personal computers and smart phones are most popular choices for the above mentioned purpose as the interfacing media for hardware - software handshake which is what this project attempts to develop and demonstrate (Greengard, 2015).

However, the project under concern deals with investigating the possibilities of this amazing piece of technology in our contemporary homes and develop a model to demo the synergies of IOT with Sustainability of the Solar Power in home environment.

2.4 Remote Sensing and Sustainable IOT Technology

Remote Sensing and Sustainability are the key proposition laid in this project with respect to the use of IOT framework. The ability to set service across specific household gadgets of daily usage with remote connection and operation without being physically available to do the same is extremely valuable and enticing idea. Furthermore a Self-sustaining system like the one proposed in the project under concern gives its user a grid free environment with Net Zero facility with no more utility bills as the user generates its own power as needed by the household (*Fedrizzi, 2008)*.

The Internet of Things has always been an enabling factor rather than as disabling factor a very good example for this is the state of the art IOT gadgetry already existing in the market known as "Alexa" or the voice-activated communications technology using the IOT framework can respond to the user voice commands for controlling connected gadgets in the home network or LAN thus giving its those special users who are handicapped or disabled to be physically controlling the home gadgets the power to control it with nothing more than their own voice. The Internet of Things as the emerging technology has always been user centric as mentioned in the above example giving its users a highly customized experience like no other.

2.5 IOT and Smart Homes

Smart Homes are the latest product of the IOT technology that's creating huge buzz. Basically a Smart Home works by connecting the home devices (both AC an DC devices) in the case of this project are lights, cctv cameras and entry door as demo items but basically any device that can be connected to the local home network or even on the internet via an interfacing medium like the personal computer so that home users can access and control those devices at will from anywhere in the house or anywhere in

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the world so to say. The user can control these connected devices using Graphical Interface or the GUI specifically developed to remotely control house lights, doors even security cameras for remote monitoring the house in absence via net connected pc or any smart phone intuitively (*Yudelson, 2008*).

2.6 Smart Home Adoption

IOT technology has come a long way since its inception in recent times from an out of the box concept to a fully developed technology being adopted rapidly. IOT has now penetrated in varied walks of life as already mentioned previously in the report it's no more a science fiction but a very well-grounded reality that has been embraced widely in the technology industry. Currently there are a wide array of IOT powered gadgets in the market like the Alexa, Smart Drones, AI Robots and not to mention household solutions like Smart Homes.

According to recent market survey, a sale of automation systems have grown to around $9.5 billion in 2015-2016 and is on the rise. It is estimated that by the end of 2017, that number could sky rocket to $44 billion in the global market (CNN, 2015-16).

However, what's amazing is that this revolutionary technology of the Internet of Things is highly attributable to the super success of smart phones and tablet computers in our regular households as a platform for the increasing adoption of IOT connected gadgets in more and more homes of today. Thus these ultra-portable forms of computers that are very common now a days, and their 24x7 Internet connectivity enables it to control a host of online devices connected on the same network demonstrating the power of the Internet of Things(Greengard, 2015).

As mentioned above in beginning of the report The Internet of Things is a terminology that refers to the devices and gadgets that are interconnected and identifiable over LAN or WAN networks enables a user to access its home appliances like lights, door, cctv cameras, ac, tv and many more such home electronic items over the internet via a pc or smart phone and switch it on or off at will with just a click of a button.

3.0 Project Analysis

3.1 Analysis Table

Based on the questionnaire developed for the project the following analysis can be derived from a sample of 15 respondents:

Questions	Yes	No	Neutral
1. Are you aware of IOT technology?	10	4	1
2. Do you use IOT technology?	9	4	2
Questions	Yes	No	Neutral
3. Do you find it beneficial?	12	2	1
4. Would you like to have a Smart Home?	12	1	2
5. Would you prefer a sustainable Smart Home with Solar Power?	14	0	1
6. Will Smart Home make your life easy?	12	2	1
7. Will Smart Home make your life hard?	3	10	2
8. Would you like to recommend it to your peers?	11	2	2
9. Would like to have a manual option as well?	9	4	2

10. How do you rate Sustainable Smart Homes on a scale of 1-5?
Respondents unanimously responded in favor of Sustainable Smart Homes with 14 respondents giving it a 5 star rating just 1 being skeptical.

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3.2 Project Methodology

Project methodology refers to the ways and means adopted as per the research standards and protocol to do the project research. Any research works involves building up a conceptual frame work for the topic chosen and devise methods to collect data regarding the same along with an apt standard to analyze the gathered data to infer a sense of purpose and goal for the research that is being carried out.

The project methodology adopted for the current project are as follows:

- Building the conceptual framework.
- Review past similar researches to build up the rational for the current project.
- Collect relevant data to back up the concepts being discussed in the project using questionnaires or existing system review.
- Review existing similar systems in the market and gain an overview of how the proposed would be developed.
- Procure the necessary hardware for the project and test it for the intended purpose.
- Select the appropriate software to develop the system that will synchronize with the hardware and test it for the same.
- Adopt a coding language of choice and platform for the system development.
- Test each component separately and in conjunction to verify compatibility.
- Develop the design outlook or system architecture of the hardware and softwarefor handshake and integration.
- Develop a rough prototype to test the proof of concept.
- Develop and design iterative versions of the system for better integration and verification.
- Once proven reiterate the prototype in terms of design and functionality until its close enough to the planned project design and system requirement specifications.

3.3 System Functional Requirements

System a requirement refers to the various functional aspects of the system to be developed as well as software or applications needed to build the system.

The various softwares requirements for the current project are as follows:

- Visual Studio 2013 for coding the System GUI for hardware integration enabling a user to control connected IOT devices like switching it on or off with click of a button.
- C# as programming language to code the GUI function buttons.
- Serial Port interfacing component in Visual Studio to connect devices to be controlled via serial comport.
- Prolific USB to Serial driver for installing the Com Port adapters.
- Windows 10 operating system as the platform and medium for the system operations as well as for device interfacing respectively.
- Team Viewer for remote desktop operations to enable the user to control the IOT devices connected to the system remotely via the internet using smart phones.

3.4 System Hardware Requirements

The hardware requirements are the hardware needed to build the proposed system in addition to the host of software as mentioned above. More often than not a system is a synergy of hardware and software to bring a system to life.

The various hardware needed for the current project are as follows:

- Solar panel to power and charge the power bank.
- USB to Serial adapter for connecting the IOT devices to the system.

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- Soldering for electronics.
- Power banks for powering the IOT devices with DC power.
- Windows Computer or Laptop for loading the system and as device interface.
- USB hub for additional serial ports to the system.

3.5 Use Case Diagram

A Use Case diagram is a graphic representation of the various interactions among the different elements or components of a system. A use case is a methodology used in system development and analysis to identify, clarify or organize system requirements.

Use Case gives the developers and the client the visual feel of the proposed system illustrating how it's going to be once developed giving the clients a draft overview of the system to be developed. Thus, Use Case diagram can be called a blueprint of the proposed system based on the foundation of which the entire system is then built.

The Use Case diagram for the proposed system are as follows:

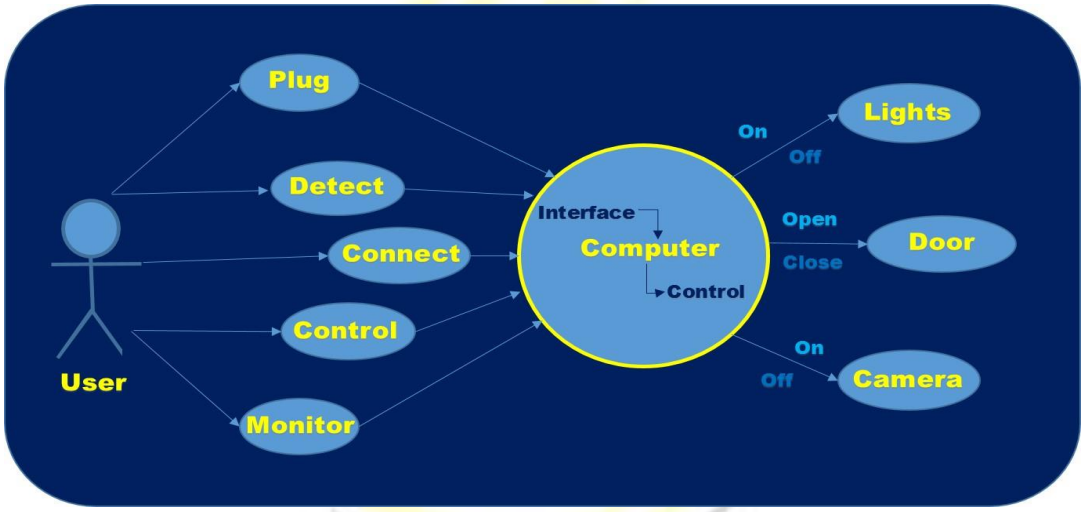

Figure showing Use Case Diagram

4.0 System Design

4.1 Design Overview

System design refers to that phase of the system development where system designers brainstorm on the look of the system interface or the GUI being developed. The project under concerns deploys the heuristics of system design by Jacob Nielsen who devised 10 heuristics to system interface design.

Any designing of a system or its interface got to follow a certain set of standards or protocol for a logical and effective well sequenced development of a Graphical User Interface so as to talk to the hardware devices connected to system which in this case are the IOT devices connected to the computer.

Nielsen's Heuristics of System Design are as follows:

- **Visibility of system status**

Any system should keep its users well informed about what is going on in the system as they navigate through the system via feedback messages or system prompts.

- **Match between system and the real world**

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The system features or icons should have some kind of association with the real world things that users are well aware about. Following real-world conventions, making information appear in a natural and logical order makes the user more comfortable and known to the system.

- **User control and freedom**

Users should have full control on their actions done in the system if something goes wrong they can always undo or redo their actions without having to get stuck or start from a fresh the system activity they were doing.

- **Consistency and standards**

There should be a consistency in the user interface where features should be set with association to the real world and in a consistent manner without losing the consistency or feel of the interface that is set throughout.

- **Error prevention**

A good system should be intuitive enough to prevent any errors before it actually happens thus giving its users error free system navigation and usage experience.

- **Recognition rather than recall**

The recognition rather than recall emphasizes on the use of system icon symbols that are self-explanatory or has some association to its actual functions like a home icon for home page or a door icon for exit thus reducing load on user's memory and enabling them to grasp functionality of the system by recognition than recall.

- **Flexible and Customizable**

The system should be so designed that it caters to both the experienced and inexperienced users equally productively and intuitively suiting to their custom needs and preferences.

- **Aesthetic and Minimalist design**

The **Graphical User Interface** should be intuitive with simplistic design and not confusing to the users thus reducing the appeal to its frequency of use. System navigation design should be self-explanatory leading its users logically and smoothly to the functions of the system.

- **Help users recognize, diagnose, and recover from errors**

System error messages should appear in plain language with no codes or signs unknown to the user to understand thus precisely indicating the system problem, and suggesting prompt solution to the users of the system to overcome or rectify the error by themselves.

- **Help and documentation**

System documentation acts as a manual of the system to the users if ever they seek any help or know how in terms of the system usage. Thus a system manual should be in a simple manner for even a novice user to get a grasp of it without any technical jargons or terminologies that might be hard to follow for the users.

4.2 System Architecture Overview

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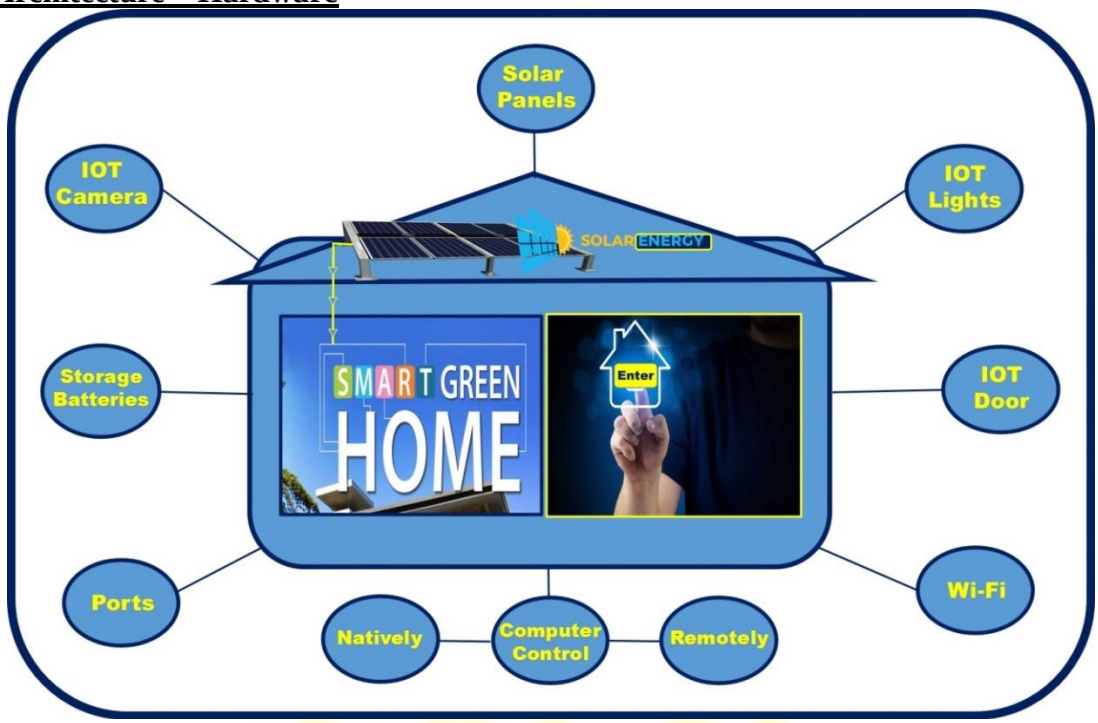
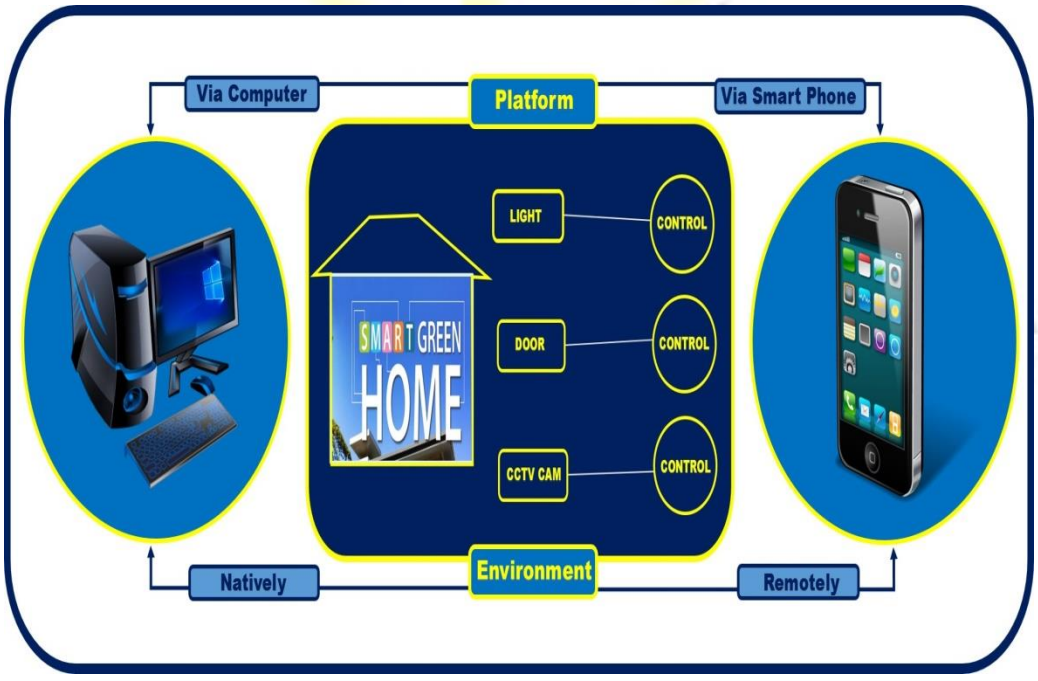
System architecture refers to the **schematics or the system blueprint** that defines the **various components in the system** and its interaction with the different users along with the direction of the flow of data in the system. It is this system architecture that lays the foundation for the entire system to build upon.

System Architecture – Hardware



System Architecture – Software



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5.0 Implementation

5.1 Implementation Overview

Implementation refers to putting together all the components developed for the system into one final system to run and test it in the testing phase. System implementation in other words refers to **deploying the finished system** at the client location and perform a series of tests to verify the **synchronization** and **integration** of the system deployed as against the **project goals** and **system functions** while track down any system glitches both in the **hardware–software** environment or fix bugs in terms of coding of the system.

5.2 Tools used in System Development

A tool used in system development refers to the hardware and software tools used in developing the system. Any system developed is usually a combination of a set of hardware and software working synergistically to become a fully functional system. The proposed system under concern as per the current project is no different and showcases a clear need for synergy and integration between the hardware components to its software elements. This hardware software integration is what referred in the project as handshake. The more this handshake is glitch free the lesser the chances of the system to break or crash ore malfunction and brighter possibilities for the system development or the project to be a successful one.

The tools used in system development are as follows:

Hardware Tools

- **Solar panel** to power and charge the power bank.
- **USB to Serial adapters** for interfacing the appliances to the system.
- Soldering for electronics.
- **Power banks** for powering the appliances with **DC power**.
- **USB hub** for extending serial ports.
- Windows 10 **desktop computer** as device **interfacing medium**.

Software Tools

- **Visual Studio** 2013 for **GUI development**.
- **C#** as programming language of choice.
- **Serial Port Component** in Visual Studio for interfacing **IOT devices**.
- Prolific USB to Serial **driver** for serial ports.
- Windows 10 operating system as the **application loading platform**.
- Team Viewer for **remote desktop operation**.

5.3 Implementation Protocol

Implementation protocol refers to the standards and procedures that are followed to implement the system at the client location. These protocols or procedures are crucial to perform successful deployment of the system as well as making the system up and running to conduct rigorous testing of the system after installation at the client location to detect any physical or logical error in the system.
In fact implementation is the necessary final step before officially handing over the system to the client after last conclusive system testing that follows post implementation. Implementation protocol is conducted with the help of a checklist with all the tests and verifications listed sequentially and

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logically to be performed on the system there after.
Successful handover depends on the positive outcomes of this implementation of the system at its intended native location of its client without any major errors and glitch free installation.
The following are the implementation procedures:

- **Assemble the different components** of the system putting the all together into one package to be transported to the client location.
- Install the finished system at client location.
- Make final **checks for missing links in terms of hardware components** verifying all the intended components are in place and installed.
- Finally, initialize the system for further testing and verification.

6.0 Testing

6.1 Testing Overview

Testing refers to the rigorous iterative testing and verification of the system functioning at multiple levels and dimension to be absolute sure of the integrity of the system. Testing is done once the implementation process is complete and the system is ready for the demonstration at client location. Once the system is initialized post implementation a series of testing takes place to verify each aspect of the system both hardware and software against real-time scenario along with a system walkthrough with the client to acquire necessary feedback.

6.2 Testing Protocol

Testing is done with a **set of checklist** called **test plan** in which all the aspects relating to the system is listed for the developers and system tester to test. Testing is **precisely benchmarking** the system to verify whether the system actually delivers what it promises or claims to deliver.

The system testing check list are as follows:

- Conduct a system walkthrough with the clients to make them familiar with the system.
- Perform a series of tests as per the predefined checklist to verify system integrity and synergy.
- Document the walkthrough.
- Perform bug fixes if any in the system's line of codes.
- Incorporate any minor additions or preferences of the clients or any exclusions.
- Test the system for hardware synchronization and compatibility issues if any.
- Verify the system integrity and coherence.
- Check for logical and structural errors.
- Run the line of codes and check it line by line for any system bugs.
- Iteratively conduct system walkthrough to detect any glitch occurring that somehow bypassed in the first place.
- Double verify the connectivity between the different IOT devices to the system and response rate between the devices as well as with the system.
- Conduct the ping test with each end of the system hardware for detecting any delay in response or dis-connectivityof the IOT devices to the system.
- Conduct a system role playing by throwing real scenario tasks to the system and monitor how it performs.
- Generate system report to verify the results of the system testing cross comparing it to the results expected.
- Finally, acquire sufficient client feedback and system acceptance by them alongside the system testing as listed above.

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7.0 Project Plan and Management

7.1 Project Planning

Project Planning is the process just after the initial project conception has been visualized and the idea is sanctioned to be developed as a project. The project planning starts off with core team meeting and brainstorming session with the client to decide on the scope and features of the system to be developed (Stevens, 2002).

The Project Planning processes are as follows:

- Plan out the scope of the project.
- Enumerate the features of the system project.
- Prepare a schedule for the relevant tasks.
- Plan out the time-line of the project from start to finish.
- Carry out Feasibility and Risk analysis.
- Undertake Cost benefit analysis.
- Prepare a resource procurement plan.
- The Project Plan is then delivered for approval by the project team.

7.2 Requirements Gathering

The process of requirements gathering refers to the research for information and data collection regarding the system requirements or the SRS through discussion sessions with client in the form of interview and through questionnaires for conceiving the system project.
The requirements gathering procedures are as follows:

- Carryout Interview sessions and send Questionnaires to collect necessary data.
- Research and review similar systems existing in the market.
- Review SRS iteratively for feature and system function refinements.
- Review the planned budget.
- The final version of the SRS document is delivered for project team approval.

7.3 Analysis

After the planning phase is completed the data gathered are then reviewed and analyzed to process the raw data into a detailed project development scheme (Stevens, 2002).

The Project Analysis processes are as follows:

- Analyze the SRS document for further refinements.
- SRS Analysis Report is prepared.
- Submit SRS report for team approval.
- Required material both hardware/ software resources for the project is analyzed for procurement.
- Preliminary design concept is then prepared.

7.4 Design

After the data collected is analyzed and SRS report is approved the project team begins designing the system's graphical interface according to the project's finalized functional and non-functional requirements in the SRS document.

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The Design processes in the project are follows:

- Review the SRS document for further detailing of the system functions.
- Developed the system architecture design.
- Prepare the prototype design based on the overview of system architecture.
- Prototype design is then reviewed.
- GUIdesign and look is then developed.
- Check for design complexity or simplicity.
- Verify the design's synergy with the overall system.
- The design concept for the GUI is then submitted for review and approval by the project team.

7.5 Development

Once the approval for the design concept is obtained the actual system build begins as according to the sanctioned SRS and Design for the system.
The processes in the Development phase are as follows:

- The system development begins with developing the UI and putting together the required hardware integrating it to the software of the system.
- After the GUI layout is laid in the programming software coding of the GUI elements starts off.
- The coding structure is logically as well as physically refined.
- Coding integration with the system and its GUI is then verified.
- The system developed is then made available for further testing and system walk throughat developer's location before implementation of the system at clients place.

7.6 Testing

Once the system development is completed the developed system goes through a series of test in order to verify the system integrity, coherence and parity with the approved SRS and design of the system.
The system Testing processes are as follows:

- A comprehensive walkthrough of the system for testing purposes is conducted alongside testing the system functioning and tracking down system loop holes if any.
- Test Analysis Report is then prepared for review by the project team.
- Test Analysis Report is then submitted for approval.
- The complete walkthrough is recorded for documentation and reference purposes.
- System Documentation is done for the entire system through the above mentioned walk through.

7.7 System Implementation

After all the series of test are conducted successfully and approved by the team the System is then implemented or installed at the clients' facility and the completed system is finally handed over to its ultimate user after a thorough final system testing on location with the client to detect any bypassed errors not occurred during the testing by the developers in the testing phase.
The system Implementation procedures are as follows:

- Install and implement the developed Sustainable Smart Green Home solution at client's location.
- Verify that all the hardware components are in place and connected.
- Hook up the system rig and initialize the system for a walkthrough as well as evaluation with the client.

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7.8 **System Evaluation**

The system Evaluation process consists of the following:

- The installed system is then run in the clients premise to give a walk through to the system.
- The system is then fully run under real scenario with actual tasks being performed by the system for functional verification.
- System is then tracked for any bypassed or overlooked error during the testing phase at the developer's side.
- After successful verification that the system is functioning as it should be the system is then officiallydelivered to the client marking the completion of the project.

7.9 System Maintenance

However it should be noted that post installation the system is monitored by the developers for an extended period on terms and condition of the project contract as post delivery service.

The system Maintenance consists of the following:

- Under system maintenance the developers monitor and deploys necessary upgrades to the client's system with their prior consent and also seek their feedback regarding the system functioning or any issues they have with respect to the system.
- If any error or system issues arise the system developers are obliged to solve the issue whether that be a system bug or a system crash all together.
- The maintenance period is dictated by the pre terms and conditions of the project with the client.
- However any maintenance beyond the service period will be performed any time with appropriate fees.

8.0 Conclusion and Recommendation

8.1 Conclusion

Harnessing renewable solar energy employing state of the art IOT technology to tap into this everlasting powerhouse is an intuitive move towards making current and future homes sustainable or self-sufficient as far as the house power needs are concerned.

The following points can be summarized as to the conclusion of the report:

- The proposed system not only harness solar energy using IOT enabled solar panels but also strives to automate homes by enabling the users to control home appliances like lights, cctv cameras or the main entry door to name a few remotely using any smart device and via personal computer.
- Smart homes and solar power goes hand in hand working as a synergistic system establishing a Micro Grid for the entire house with its own power supply and management system.
- The system also enables the users to monitor their homes in their absence via the IOT camera connected to the central home computer using any available Remote Desktop apps.
- The system is also modular in nature where any home device can be interfaced to the computer by the interfacing mechanism of the system to be controlled by its intuitive GUI.
- The possibilities with this IOT powered system are endless.
- This particular system can also be used automate garden or private entrainment room and our HTPCs.
- This project is a model or sneak peek into what can be possible with the power of IOT as emerging technology of the future.

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- The system under consideration is a move towards greener cleaner environment for the future with less carbon footprint on the planet.

8.2 Recommendations

The following recommendations are enumerated for the current project:

- Even better planning and time management.
- Keeping the system simple and logical.
- Testing each component for compatibility and synchronization with the system before actually adding it to the system.
- Show casing the varied use of the IOT power by controlling even lager array of home devices.
- Develop several versions of the system as backup rather building just one so that any error can be tracked back and rectified.

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