Practical Issues on Constructing Hybrid Smart Homes

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***Abstract*—Smart homes provide comfortable, safety, sustainable, and health caring services for people live in. A smart home does not need to have everything be smart. For majority of people, making part of traditional appliances smart and adding some of services which were not exist in traditional home is enough. It is called hybrid smart home. In this paper, issues on constructing a hybrid smart home in which smart elements are coexist with traditional elements are discussed and special attention is on electrical wirings. On constructing a new smart home or renewing a traditional building to smart one, the wiring approach is different from traditional one. Several concepts for wiring about this issue are proposed and demonstrated in this paper. First concept introduces a lighting switch called bypass used upon malfunction of smart system to guarantee availability of lighting. Second concept discusses type and installation of lighting switch, so that it can coexist with traditional switch and would not cause ambiguity to inhabitants. The experience learnt from the pilot test which was conducted at an actual smart home was discussed.**

***Index Terms*—Bypass switch, Distributed Control Module, Tibbo**

I. Introduction

Smart homes have gradually become a new type of living; the main reason is that advances in technology and human demands for improvement in the quality of life. Smart homes provide an environment with safety, health caring, energy sustainability and comfortable. The fast proliferation of information technology is within a couple of decays. Young generation is called digital natives [1] who are born to familiar with the information tools. In contrast, the older generation may not familiar with information technology even uneducated. When constructing a smart home, the habit of family members should be taken into consideration. It can expect that a smart home with fully equipped brand-new technologies (or fully computerized) may not be a friendly space for older people at least their past experiences may not work. Paradigm shift takes time, transferring from traditional to smart home not only should consider living experience of residents but also working experience of other participants such as building constructors, electrical circuit designer, and installer. During transition period, related personnel must have sufficient time to get familiar with new technology. Currently, any electrical wiring of a home installed by an electrician, other electrician can easily understand due to they are at the same technology basis. In contrast, a dedicated smart system installed by a company, another company may need to pay a lot of time to understand it. In addition, lightings and home appliances do not need to totally be smart. Occasionally, people put a lot of efforts and resource to perform a smart task which can be done instantly in traditional way.

Cost is a major issue when people consider building a smart home. In spite of cost, a few people refuse to live on a smart home. Cost consists of construction and maintenance. With regarding to construction cost, if no special requirement, it has better no to use brand new technology instead of mature ones. In addition, people sometimes ignore the maintenance cost which includes operation cost (energy cost) especially communication cost and the cost of maintenance personnel who may be a dedicated or sharing with others. Information technology is changing quickly, therefore system scalability and expandability on a smart home is necessary, so that it is easy to introduce advanced and mature technology to reinforce system functionality. A smart home has more chance to upgrade or add new equipments with comparing to a traditional one. And these new equipments need maintenance in the future. Therefore it should take the cost of maintenance, upgrade, and replace into consideration on a smart home. It has better to care MTBF (Mean time between failures) and MTTR (Mean Time to Repair) issues. Besides, it should avoid taking giant leap on technology instead of using contemporary engineering technology which complies with people custom on building or renewing a smart home. In other words, it should not let residents or engineers are far away from their familiar custom or skill unless most of the living spaces are smart. Furthermore, it should have vision on constructing smart home (future consideration) not just chase new fashion style; it also should take reality into consideration. More importantly, it should not fully technology-oriented thinking, but keep sustainable survival concept on mind. If only take technology in mind, it may consume more resource than saving.

There are two electric circuitries on a typical living space in Taiwan, one is for lighting another is for power sockets which are classified into to 110V and 220V on supply voltage, the latter one is for air conditioners or heating normally. A lighting device is controlled at least by one switch, sometimes by two switches such as for up/down stair lighting. The principle of placement for installing lighting switch is as convenient as possible such as at the entrance of living room. It is a normal arrangement and most of people familiar with it. When constructing a smart building, it should not totally abandon this habit instead of introducing a brand new style.

In this paper a hybrid approach to construct a smart home is proposed which takes the above mention issues into consideration. An example system was built and tested; the

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result was satisfied by users who live in such a hybrid smart home.

II. Backgrounds

A. Smart Home

Smart home was first official introduced by American Association of House Builders in 1984 [2]. The free dictionary defines smart house is a highly automation house in which not only audio/video entertainment facilities are networked, but also air conditioner and lighting control are networked as well. Network service can be accessed everywhere in house, such that electrical appliances at any place may be interconnected with other devices [3]. Aldrich [2] defined a smart home is a place that equipped with computing and information technology, and can accept as well as reply resident's request. The purpose is to provide resident a comfort, convenient, safety, and joyful life through managing various technologies at home and outside world.
The Japanese government defines smart home is an information house. Currently, special attention is paid on energy saving and carbon emission reducing. It is expected to control energy usage efficiency through connecting electrical appliances and related devices in house with information network. The Korean government initiates short, medium, and long term milestones as digital home (~2009), smart home (~2012), and convergence home (~2015) respectively. Ministry of Economic Affairs of Taiwan established Smart Living Technology Promotion Office and proposed i236 project in 2009. The goal of this project is to develop 20 kinds of technologies for applying to smart living, and actually used in smart town and smart commerce and trade park within five years.

B. Hybrid Smart Home

Currently, hybrid smart home does not have a consistent definition. Regardless of topic, it mixes two or more things or technologies. However, the general concept of hybrid refers to energy, especially on electricity. Such as Allan Nicholson defines a hybrid smart home is powered by a combination of solar panels, LPG gas, a back-up diesel generator and a battery bank which allow the house to generate its own power [4]. In this paper hybrid refers to mix up of traditional and modern technology. In general, a contemporary smart home uses central control approach such as using iPad or iPhone as user interface. In such manner, user controls electrical appliances such as air conditioner, lamps, or fans with iPad or iPhone. In contrast, electrical appliances are controlled by individual switches which are embedded onto wall. In hybrid smart home, traditional and contemporary approaches are coexisting. For digital native generation, they can use iPad to access appliances, while the older generation access appliances with traditional switches.

C. Embedded Systems for Smart Homes

There are several approaches to implement controllers for smart homes which should satisfy following requirements:

- Robustness: systems should run without malfunction as long as possible, and it should have better mean time to failure (MTTF).
- Simple: the controller is home use, therefore it should be easy to install and maintain.
- Scalability: technology advances quickly and people's thinking may be changed from time to time, therefore system should be easily updated and expanded to fulfill long term requirement.
- Approximate to current experiences: nowadays, there are not many skillful technicians who have ability to plan, install and maintain smart system at home. The smart systems may be installed and maintained by technicians who have not many experiences on advanced systems; therefore, if the process of installation and maintenance is far away from their experiences, it may cause some troubles.

According to above discussion, the possible configurations are as following:

- Dedicated controller: it is a controller dedicated for smart home. Owing to market of smart living space is not big enough, there are no many such kinds of systems; Creston is one of such system providers [5]. Its advantage is dedicated design for smart living space, so may have more suitable features; its disadvantage includes maintenance consideration and cost may be higher.
- Desktop computer with input/output card: it adopts common desktop computer as platform and adds input/output control card. Owing to such system uses common components and application software may be programmed with popular programming languages, therefore its cost may be reasonable and expandability is higher. In contrast, its disadvantage is robustness and stability. This configuration is rare on smart home.
- Desktop computer with discrete control module: it adopts popular desktop computer with discrete distributed control module. Distributed control modules are popular at factory automation, therefore they have better stability. This kind of modules communicates with computer through communication interface such as RS485 or TCP/IP, the latter approach is getting popular. This configuration satisfies robustness, stability and reasonable cost.
- Popular industrial controller: the most popular industrial controller is programmable logic controller (PLC). Its major application filed is industrial machinery, its control capacity ranges from compact one which has tens controlling points to huge one which may have hundreds even thousands of controlling points. It usually has network or communication function to communicate with computers.

Recently some miniature single board systems with well-designed I/O, communication, and software development tool are emergence. Arduino and Tibbo are two examples. In order to assist students reduce cost of developing an interactive project, the staff of a university in Italy developed a system called Arduino which is based on Atmel AVR microcontroller in 2005 [6]. Arduino system contains the Arduino board and IDE development environment. A typical Arduino specification is as follows: dozen digital I/O points, several analog I/Os and USB interface for powering and communication. Its major applications are interactive arts design, small scale control. Riley proposed a serial implementation of Arduino for smart

home [7]. Tibbo is a serial SOC (system on chip) based controllers developed by Tibbo Technology [8]. It is intended for small scale industrial control. Its typical specification is as follows: dozen digital I/O points, Ethernet interface, build in web server, and virtual machine for running Tibbo basic programs. With regarding to smart home implementation, Tibbo is superior to Arduino although the latter is more popular and widely used.

III. System Design

Most of electrical circuitries at a home are for lighting and power socket. Wiring comes out from breaker (usually a No Fuse Breaker) on distribution panel, goes through light switch, lighting bulb and back to breaker. In general, lighting switching has two stable positions one for ON and another for OFF. This switch usually is located nearby the corresponding lighting for convenient (refer to Fig. 1). This switch can be replaced with several alternatives in a smart home: 1) totally omission, 2) an integrated panel, or 3) a push button. Omission means switch is omitted and lighting is completely controlled by the system. Traditional switch may be replaced with an integrated panel. The advantage of this approach is that people may control several lightings at same place, and the obvious disadvantage is cost. Switch may be replaced with a push button. Lighting on a smart home is not only controlled by hand, but also by system. If a traditional switch is adopted; and lighting is set to ON status by hand. At this moment the switch is at ON position. Later, if the lighting is switched to OFF status by system automatically with predefined control logic. Then ambiguous happens. Since switch is on ON position but lighting is OFF. If switch is replaced with push button, this ambiguous disappears since a push button only has one steady state.

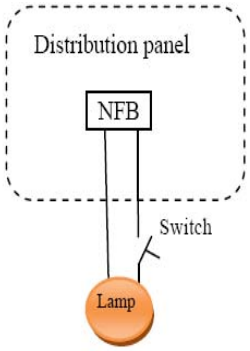

Fig. 1. Traditional wiring of lighting

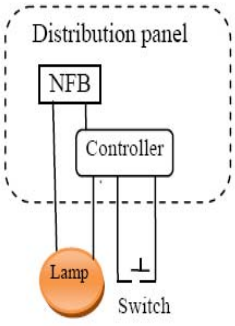

Fig. 2 Wiring of lighting in an IH

In addition to the abovementioned issues, traditional and smart lighting control has following different considerations. A traditional lighting control switch is a robust element which has lifespan as long as building itself unless certain circumstance occurred (such as short circuit). In contrast, the robustness of smart controller is weaker than traditional one. Unless industrial grade controller is adopted; occasionally malfunction will occur. In general, the mean time to repair of a smart controller is longer than traditional one. Do it yourself (DIY) is a common activity nowadays, it is not much difficulty to replace wiring of lighting; it also can easily find an electrician who can perform this task when searching help from outsource. While it is not easy to DIY the above task at smart home, sometimes it takes certain time to fix it by a specific domain expert duo to smart living space is not a common style currently.

Therefore, it should add a bypass switch from practical viewpoint. This bypass switch can switch on/off lighting as traditional switch does. A bypass switch is used to control lighting while smart controller is being malfunction. Its installation location is less constraint such as inside of distribution panel due to avoiding confusion with traditional one and rarely using.

Another common circuitry is power socket which should consider more aspects with comparing to lighting on a smart home. The appliances commonly used at home are diverse. These appliances are quite different with regarding to power consumption, type of loads, and supply voltage. For example, the power consumption may range from several watts to thousands of watts; the type of loads may be pure resistance type such as heaters to inductive type such as motors. Therefore, it should take these parameters into consideration when designing smart control of power socket. In addition, lighting circuitry may not be altered once it has been installed, for example replacing lighting with a heater. In contrast, due to the appliance plugged into power socket may be changed occasionally, the power consumption is variant. Regardless of control strategy, what kind of capacity should be adopted is a big issue. The traditional circuitry for a power socket is usually connected to breaker (such as NFB) at distribution panel. At a smart home, power socket should be controllable; therefore a switch which is controlled by smart system should be placed between power source and the power socket. If there is no sufficient information, a contact with capacity of 250V, 10A may be adequate. Contacts could be traditional power relay or solid state relay (SSR). Besides, the contact should be normal close (NC) type such that power socket has power available during system malfunction.

It has not much appliances needed to be smart other than lighting and power socket. In fact, most of home appliances are controllable with automated power sockets. Therefore, the abovementioned considerations cover most of the requirement.

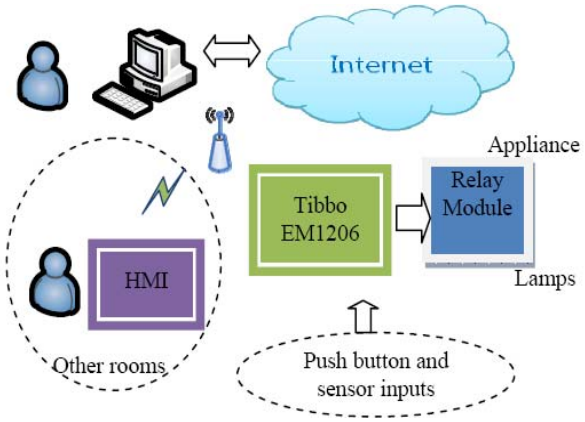

Fig. 3. System configuration

IV. System Implementation

The proposed hybrid system has been installed on a newly built house for about half a year, it functions properly. The

configuration of this deployment is as shown in Fig. 3. The main controller is Tibbo EM1206. Tibbo has built in web server, Ethernet connection and digital I/O (input / output). This configuration makes it an idea controller for hybrid smart home deployment. Users can access functions on Tibbo controller with three approaches: local switches, remote HMI (such as iPad), or sensor inputs.

In summary, the hardware configuration is as follows:

- EM1206: Tibbo embedded system serves as system controller and web server. It connects to Internet with RJ45 interface.
- Relay module: it serves as interface between EM1206 controller and final controlled appliances (such as lamps).
- Push buttons: they serve as traditional lamp switches.
- Tablet PC: it serves as mobile human machine interface for connect to Tibbo to control lamps or appliances and recognize current status of these appliances through web browser.

The system operation flow is shown in Fig. 4. When user press button on web page, web server will process this request and forward the command to Tibbo main program to perform control action. In contrast, if user press traditional switch on wall, it will trigger an I/O interrupt to Tibbo main program to perform control action. The status of home page will be updated every 5 seconds to let users monitor current status of the smart home.

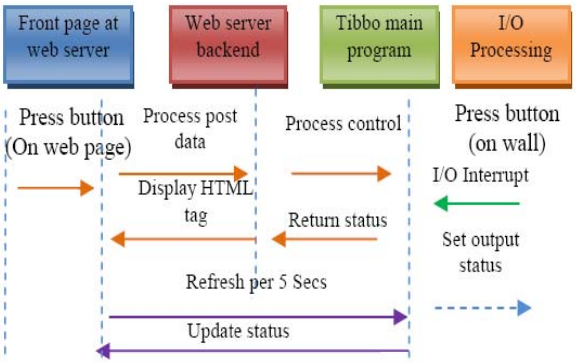

Fig .4.

The bypass switch is also installed in this house; the concept diagram of bypass switch is shown in Fig. 5. It is parallel with Tibbo controller that means it can override the control of Tibbo when Tibbo is malfunction. No any man made system can work correctly forever, when it break down, bypass switch can be an alternative way to access lamps.

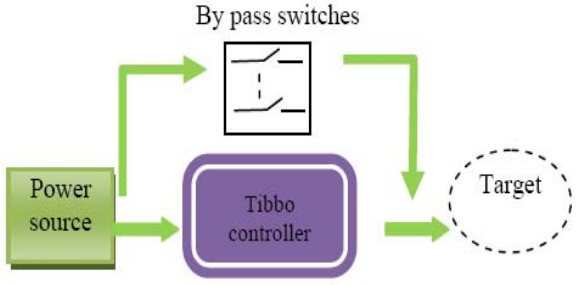

Fig. 5 Bypass switch location

V. Result and Discussion

This implementation has been run for over half a year. At this period, there is no any malfunction occurs and family members are familiar with this configuration. In other words, despite the remote access through web browser, this smart configuration is same with the traditional one from operation point of view.

For a normal lighting, it is controlled by three approaches: 1) bypass mode: it is for emergency use when system malfunctions, it is one of key features of the proposed configuration; 2) field mode: it is a normal operation mode, users control on/off of lighting with discrete switch located at traditional location; 3) remote control mode: users can control on/off of lighting through web browser remotely. For power socket only third mode (remote control) is provided which complies with user's past experience. Inside of distribution panel. For demonstration purpose, it is at outlet of the panel in this implementation (refers to Fig. 6, 7). The switches for smart control and traditional switch are at same location. It is quite similar; therefore any family member especially elder member can get familiar instantly.

Fig. 6. Bypass switch

Fig. 7. DS panel

A snap shot of web page is shown in Fig. 8; it is a simple user interface. If it is necessary, more user information may be added. Fig. 9 shows an actual wall mounted switches. As mentioned before, not all traditional lamps or appliances need to become intelligent. The two switches on left hand side are connected to Tibbo and the switch on right hand side is a traditional lamp switch.

From cost point of view, the proposed system has following elements: Tibbo, power supply (DC5V, 24V), power relay, and wiring. The cost of control unit and power supply is about 150 US dollars. The wiring cost is small amount. Another cost comes from operation. It consumes about 0.5 KWH daily measured by a digital power meter. In summary, no matter from cost of building or operation point of view, it is acceptable.

A few questions were found during constructing stage. It is a new wiring scheme, although best effort was put to keep this scheme as simple as possible, a electrician took a certain time to comprehend it when system engineers gave these wiring schemes to them because they had no such experience. Lin et al [9] had mention that reeducating the personnel work at field is necessary at the beginning of promoting smart living space.

Fig. 8. Snapshot of web page

Fig. 9. Traditional switch and push button switches

VI. Conclusions

A more practical approach on installing wiring of an smart home and concept of bypass switch were proposed. The smart system installed should run 24 hours a day. It sometimes introduces backup system to maintain uninterrupted operation on factory automation that has two systems run simultaneously. Equipments on an automated factory are for creating profits, therefore it is reasonable to invest two identical systems. This configuration is not adequate solution for smart home. To prevent causing family members inconvenient or even unsafely by system malfunction, a simple yet practical backup facility is necessary. For lighting and power sockets which are common devices at smart home, the bypass switch and normal close contact are introduced respectively.

Another viewpoint proposed in this paper is that more practical consideration on requirements should be performed instead of making everything be smart. The case study of the pilot system presented acts as reference for building an smart home.

Acknowledgment

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