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Fuzzy-Based Energy Management System For Green Houses Using Grid-Solar Power

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Abstract

Today, we are seeing a rise of global awareness of energy consumption and environmental problems. Many nations have launched different programs to reduce the energy consumption in residential and commercial building to seek lower-carbon energy solutions. Our paper is about the future green and smart house. The subject of smart/green houses is not one of "why" but rather "how" specifically: "how making the future house more energy efficient." The use of the renewable energy, the technology and the services could help us to answer to this question. Intelligent home energy management is an approach to build centralized systems that deliver application functionality as services to end-consumer applications. The objective of this work is to develop a smart and robust controller for house energy consumption with maximizing the use of solar energy and reducing the impact on the power grid while satisfying the energy demand of house appliances. We proposeda Fuzzy-based energy management controller in order to reduce the consumed energy of the building while respecting a fixed comfort.

Keywords *Rrenewable energy system, Fuzzy-based energy management controller*

I. INTRODUCTION

The depletion of non-renewable resource fuels such as gas, coal and petroleum is on one hand and the global climate change, and awareness of the impact of harmful emissions on health and the environment on the other hand has led to an increased interest in the way we are using the energy.

Renewable energy is energy that comes from resources which are continually replenished such as sunlight, wind, rain, tides, waves, biomass and geothermal heat. Nowadays there exists a wide range of technologies which possess this capability.

However, the most energy and environmental gains can be achieved by focusing efforts on improving the energy efficiency in residential and commercial buildings.

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In the short term, the energy conservation will certainly become the most important issue to address amongst engineers, researchers and environmentalists with the rising consumption of resources and deterioration of the environment.

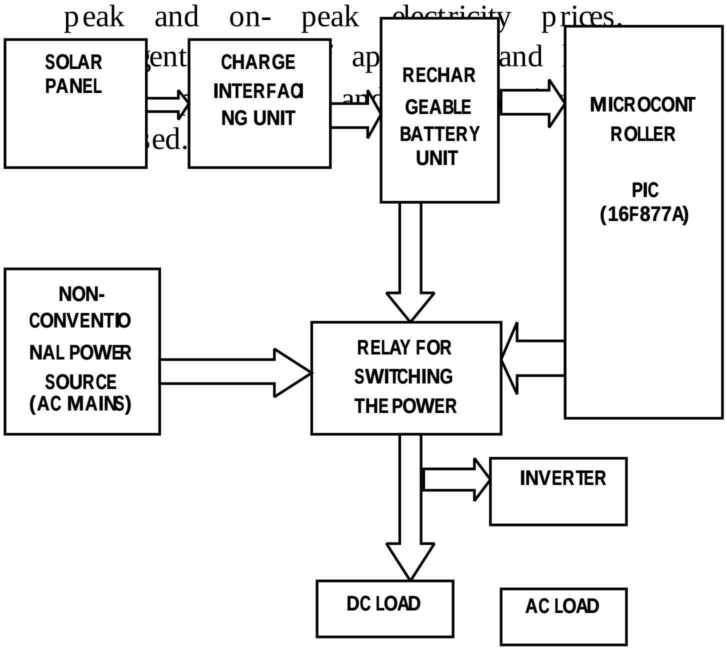
Conserving energy would reduce the rise in energy costs, and can reduce the need for new power plants. The reduced energy demand can provide more flexibility in choosing a cleaner and efficient method of energy production.

Reduction in theemissions would certainly less hazard caused to the environment. In other terms, energy conservation is often the most economical solution to energy shortages, and is a more environmentally friendly.

Considering the large energy consumption of the residential-building sector, efforts to decrease energy use and negative environmental impact is an important national and international issue. The residential sector should play a major role in bringing new energy efficienttechnologies to the forefront. To further emphasize the importance of creating more energy conscious housing it is important to look the impact that cities built form have our natural resources and energy consumption.

However, with populations increasing along with the urbanization of cities, cities have become the main culprits of poorly managed natural resource consumptions.

The energy efficiency of appliances, lighting, HVAC (heating, ventilation, and air conditioning), and building materials must continue to improve. Unfortunately, the homeowners often unaware of the technology and materials available, or have negative impressions of the cost or ease of installation. Both of these concerns must be addressed for a positive impact in residential buildings to be achieved.The proposed energy management controller is based on user behavior, time-of-use rates, the off-peak and on- peak electricity prices.



Block digram of Proposed Method

II. RENEWABLE ENERGY SYSTEM

The worldwide rise in energy demand accompanied by the rise in prices of petroleum products has led to a profound

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change in the present day energy infrastructure. The actual electric power infrastructure in most of the developed country is running near capacity.

There is increasing consent among governmental policy, business leaders, and other key electric grid stakeholders to develop a technologically enhanced electric grid. In the near term, the most promising marriage of the electric grid and newinformation and communications technology will yield the concept of the smart grid.

The smart grid can be defined as an intelligent grid having the capacity to be extremely efficient and deliver energy at an affordable cost in the decade of high inflation.

Nowadays, either in industry, government policy and or in academia has identified the following aspects that need to be considered when designing a future electric grid:

- Electric power causes approximately 25 % of global greenhouse gas emissions and utilities are evaluating the need for a more green electric system.
- Renewable and distributed power generation will play a more prominent role in reducing greenhouse gas emissions.
- Real-time monitoring of grid performance (e.g. agents deployed along the electric line) will help identify the concerns over grid reliability thereby increasing gridreliability and utilization, reducingblackouts, and increasing financial returns on investments in the grid.

One of the important applications of smart grid is that it encourages home and business owners to invest in micro generation technologies in order to supply some of their own energy and reduce the demand on the electric grid.

Among the various renewable energy resources, the most popular sources are the solar and wind energy. These energies are non exhaustive, site-dependent, and green. Micro generation models consist of various sources of energy such as wind turbines, Photo Voltaic (PV) panels, fuel cells, etc. The combination of these energy sources in different patterns results in multiple designs of Hybrid Renewable Energy Systems (HRES).

The hybrid renewable energy systems can be generalized as a system that utilizes electric power from both conventional grid as well as from the renewable sources. Compared to the actual electrical grid, the HRES could reduce dramatically the fuel consumption. Also, the HRES could decrease the consumer electricity bills through the use of energy efficient appliances and by monitoring the time of consumption of electricity.

Last by not least, the HRES can reduce CO_2 emissions through efficient generation and minimizing thermal generation. As a result, HRES could makethe system cost-effective, green, and highly reliable in terms of producing power.

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III. SOLAR POWER

Solar power is one of the fastest growing renewable energy technologies and it is expected that it will play a major role in the future global electricity generation mix.Solar PV systems are also one of the most “democratic” renewable technologies, inthat their modular size means that they are within the reach of individuals, co-operatives and small-businesses who want to access their own generation and lock-in electricity prices.

The smart house includes an off-grid solar power system, where the solar array was sized to produce 100% of the energy required to run the home year-round. The system is called “off-grid” because it is not intended to be connected to the nation’s electrical grid.

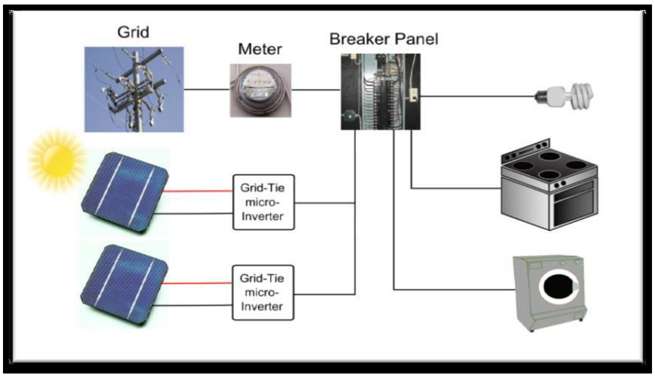

Fig.1: Power System Using Electrical Grid and Solar Power

A diagram of the power system can be seen inFigure 1. The system consists of a quantity of photovoltaic modules that provide power to a battery charge controller. The charge controller regulates the voltage to safely charge a set of batteries. An inverter that simulates electrical grid quality power is connected to the batteries to provide alternating current power to the house.The solar panel only produces energy while the sun is shining. If electricity is desired at other times some sort of storage is needed. Most solar electric systems use batteries to store the energy from the solar panels. The advantage with such technologies is that they are small, cost effective, reliable compared to traditional large power plants.

IV. FUZZY BASED ENERGY MANAGEMENT SYSTEM (EMS) FOR A SMART HOUSE

Houses are becoming smarter in that their ability to reduce energy usage is increasing. Traditional stand-alone, complex systems that manage various appliances are now converging towards a common wireless wire-line infrastructure that allows these devices to communicate with each other and coordinate their actions which can reduce the consumed power. The smart home is modeled in discrete time. Hence, all electrical quantities are modeled as energy blocks.

The energy management problem is defined as a load side demand management

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problem where the charging demand is controlled to optimize the operation of the grid. The power split on the source side ismanaged by a simple rule such that the PV panels get first priority and supply maximum possible power. The remaining demand is supplied through the grid.

In this work we proposed a smart house energy management based on Mamdani's Fuzzy Inference System. It was designed to reduce costs for the householder. **Figure 2** illustrates the framework of the Fuzzy-based Inference System for Energy Management System.

The objective of the energy management controller is to control the charging power of the consumed energy such that the grid power utilization is minimized particularly during the peakperiod.

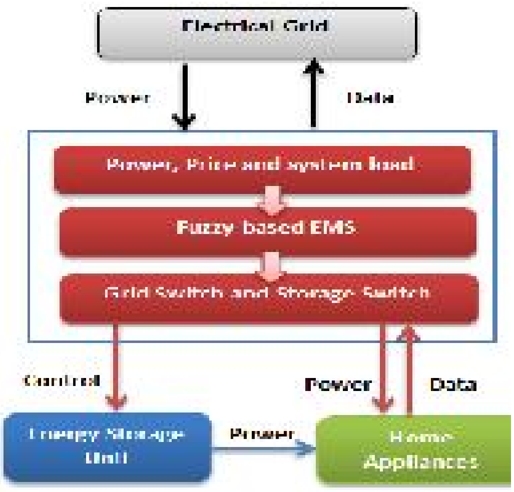

Fig.2: Fuzzy Based Inference System for Energy Management System

In continuous time, the optimal control problem:

$$P_{ap}(n,t) = argmin \int f\,(P_{grid}(t))\,dt$$

With power and energy balance equations

$$P_{grid}(t) = \sum_{n=1}^{N} P_{ap}(n,t) - P_{solar}(t) - P_{bu}(t)$$

$$\int_{day}\left(P_{solar}(t) + P_{grid}(t) + P_{bu}(t)\right)dt - \int_{d} \sum_{n=1}^{N} P_{ap}(n,t) = 0$$

In the above,P_{solar} (t) is the solar power,P_{grid} (t) is the grid power,$P_{bu}(t)$ is the power ofthe batteries (i.e.backup systems).

These batteries could be charged by the solar system or by grid during the peak-off time. The$P_{ap}(t)$ is the consumed power from the house appliances.

The main problem is now is to find time to switch from PV to grid and from the grid to PV and vice versa. The switching point should take into consideration the available power at $P_{bu}(t)$, the user behavior, time-of-use rates, the off-peak and on- peak electricity prices.

As shown in Figure 3, smart meter connects the traditional grid, energy storage unit (or backup system) and the other the house appliances. Smart meter receives power information from distribution grid which contains power price and grid load. The integrated Fuzzy-based EMS will process the input of price and load, and generate output which will be sent as a control signal to operate grid switch and storage switch.

The control signal sent to grid switch will determine how smart meter directs electricity from the distribution grid to energy storage unit and other household

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appliances. The control signal sent to storage switch will operate the energy storage unit and it will decide whether an energy storage unit is charging or releasing.

Figure 3 illustrates the rules of Mamdani's Fuzzy Inference System. The system is composed of two inputs. As shown in this figure, the input 1 represents the electricity price (low, medium and expensive) and input 2 is backup unit load (low, medium, high). Output is the signal that controls Energy storage unit. Furthur rules represent the knowledge base which determines how FIS works. These rules are based on consideration of cost reduction for the householder.

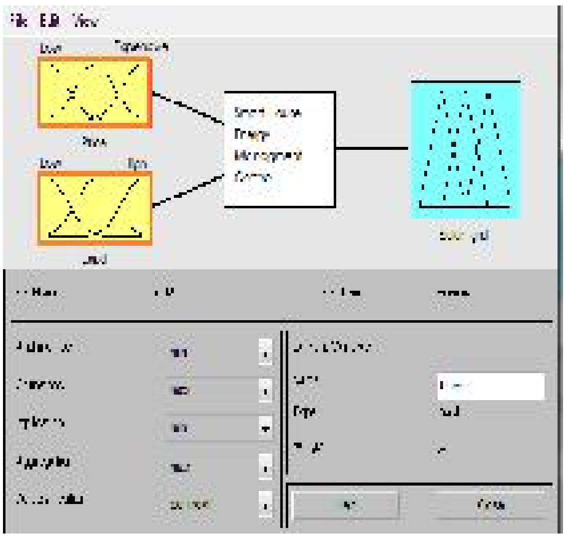

Fig.3: Rules of proposed Mamdani's Fuzzy Inference System

Trend 1: When power price is cheaper, the backup system is charging more

Trend 2: When power price is more expensive, the backup system is releasing more.

Trend 3: When PV is higher, the backup system is charging more.

Trend 4: When PV is lower, the backup system is releasing more.

The backup power system will be used mainly when the electricity price is expensive and when the solar system is not available (during the night or cloudy day).

IV. SYSTEM EVALUATION

The daily electrical requirements were estimated for the house. This estimate required the specification of all of the appliances that would be used in the house. The results of the electrical use estimation typical house are shown in Table 1.

As seen in Figure 4(a), there exists three time period(s) during the day characterizing peak demand of electricity. Figure 4(b) shows the hourly power price curve of a typical day. The curves show the On-peak (when demand for electricity is highest); Mid-peak (when demand for electricity is moderate); and Off-peak (when demand for electricity is lowest).

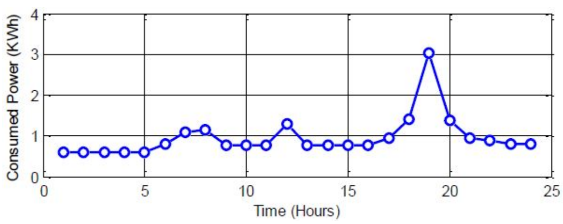

Fig.4(a): Typical household electricity consumption pattern

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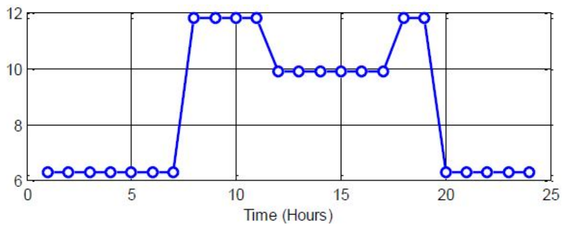

Fig.4(b): Typical hourly power price

Appliance	Power consum. (watts)	Usage per day	Daily power consumption (W/h)
Refrigerator			
• Refrigerator	45	24 hours	1080
• Freezer	52	24 hours	1248
Cooking			
• Electric range	365	4 hours	1460
• Microwave	60	10 min	10
• Coffee maker	30	10 min	3
• Toaster oven	50	10 min	5
Laundry			
• Dryer	1500	1 hour	1500
• Washer	500	1 hour	500
• Iron	50	10 min	300
Entertainment			
• Color TV	100	5 hours	500
• Stereo	100	3 hours	300
• Computer	60	3 hours	180
Heating			
• Water heating	180	20 hours	3600
• HVCS	250	24 hours	6000
Other			
• Lighting	300	6 hours	1800
• Cell Charging	8	4 hours	32
• Car block heater	200	2 hours	400

Table.1:Typical household electricity consumption pattern

The size of the solar array required for a given load and level of sun hours can be calculated with below equation. The calculations show the minimum size for the installation is 316.5W

$$Load\left(\frac{Wh}{day}\right) = 316\ W * 5\ h/day = 1580\ \text{Wh/day}$$

Figure5(a) shows the load curve of household without using the PV power or only when the house use the distributed grid (red line), then when the house is equipped with a PV system but without EMS control (blue line) and finally when the house is equipped with both PV and fuzzy-based EMS control (green line).

Figure.5(b) shows the hourly cost of power consumption of the three configurations.

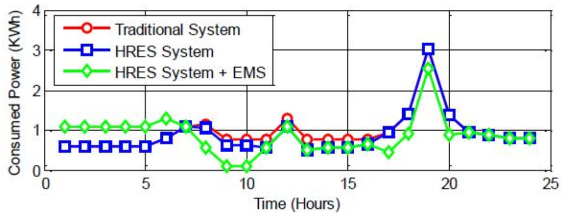

Fig.5: (a) Load curve for the three systems

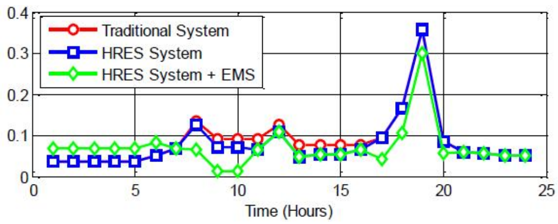

Fig.5:(b) Hourly Cost Curve of three systems

Based on these results we could estimate the monthly electricity bill for the three systems.

The bill is high for traditional system compared to HRES-PV system.The householder could decrease more his bill if the system uses an EMR controller.

V. CONCLUSION

The concept of smart home energy management involves the integration of

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various appliances with a smart control unit capable of bidirectional wire-line or wireless communication between the controller and the utility. One problem that arises with these features is various compatibility issues between the different appliances, various smart controllers, and communication protocols. The results demonstrated that the proposed EMS controller provides a better strategy compared to the conventional method for cost saving.

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