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Controlling of grid connected photovoltaic lighting system with fuzzy logic

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Abstract

In this study, DC electrical energy produced by photovoltaic panels is converted to AC electrical energy and an indoor area is illuminated using this energy. System is controlled by fuzzy logic algorithm controller designed with 16 rules. Energy is supplied from accumulator which is charged by photovoltaic panels if its energy would be sufficient otherwise it is supplied from grid. During the 1-week usage period at the semester time, 1.968 kWh energy is used from grid but designed system used 0.542 kWh energy from photovoltaic panels at the experiments. Energy saving is determined by calculations and measurements for one education year period (9 months) 70.848 kWh.

Keywords: Illumination; Photovoltaic energy; Fuzzy logic; Energy saving

1. Introduction

Electricity is the most versatile form of energy we have. It is what allows citizens of the developed countries to have nearly universal lighting on demand, refrigeration, hygiene, interior climate control in their homes, businesses and schools, and widespread access to various electronic and electromagnetic media. Access to and consumption of electricity is closely correlated with quality of life. The Human Development Index (HDI) is compiled by the UN and calculated on the basis of life expectancy, educational achievement, and per capita Gross Domestic Product. To improve the quality of life in many countries, as measured by their HDI, will require increasing their electricity consumption by factors of 10 or more, from a few hundred to a few thousand kilowatt-hours (kWh) per year. How will we do it? Our choices are to continue applying the answers of the last century such as burning more fossil fuels (and releasing megatons of CO_2, SO_2, and NO_2) or building more nuclear plants (despite having no method of safely disposing of the high-level radioactive waste) or to apply the new millennium's answer of renewable, sustainable, nonpolluting, widely available clean energy like photovoltaics and wind (Luque and Marti, 2003).

Nowadays, photovoltaic (PV) systems that supply power directly to the grid represent an important energy alternative due to the new laws and policies favorable to renewable energy that have been created lately. The main components of a grid connected photovoltaic (PV) system include a series–parallel connection arrangement of the available PV panels and a power conditioning system in charge to transfer energy to the grid or transfer from grid (Meza et al., 2006; Meinhard and Cramer, 2000; Sang-Hun et al., 2008).

The problem of energy saving and the achievement of visual comfort conditions in the interior environment of a building is multidimensional. Scientists from a variety of fields have been working on it for quite few decades, but

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it still remains an open problem. People spend about 80% of their lives inside buildings. So, achieving lighting comfort conditions in a building is very important and has direct implication to the energy efficiency of the building (Alexandridis and Dounis, 2007).

The photovoltaic (PV) effect is the electrical potential developed between two dissimilar materials when their common junction is illuminated with radiation of photons. The PV cell, thus, converts lights directly into electricity. A French physicist, Becquerel, discovered the PV effect in 1839. It was limited to the laboratory until 1954, when Bell Laboratories produced the first silicon cell. It soon found application in U.S. space programs for its high power-generating capacity per unit weight. Since then, it has been extensively used to convert sunlight into electricity for earth-orbiting satellites. Having matured in space applications PV technology is now spreading into terrestrial applications ranging from powering remote sites to feeding utility grids around the world (Mukund, 2006).

The main applications of photovoltaic (PV) systems are in either stand-alone (water pumping, domestic a street lighting, electric vehicles, military and space applications) or grid connected configurations (hybrid systems, power plants).

Unfortunately, PV generation systems have two major problems: the conversion efficiency of electric power generation is very low (9–17%) especially under low irradiation conditions, and the amount of electric power generated by solar array changes continuously with weather conditions (Faranda and Leva, 2008).

Efficiency is an important matter in the photovoltaic (PV) conversion of solar energy because the sun is a source of power whose density is not very low, so it gives some expectations on the feasibility of its generalized cost-effective use in electric power production. However, this density is not so high as to render this task easy. After a quarter of a century of attempting it, cost still does not allow a generalized use of this conversion technology.

Efficiency forecasts have been carried out from the very beginning of PV conversion to guide the research activity. In solar cells the efficiency is strongly related to the generation of electron–hole pairs caused by the light, and their recombination before being delivered to the external circuit at a certain voltage. This recombination is due to a large variety of mechanisms and cannot be easily linked to the material used to make the cell (Luque and Marti, 2003).

In this study, solar energy, which is a kind of renewable energy source, is converted to electrical energy and used for lighting system. System is designed considering energy saving and lighting comfort together, because the produced energy is limited due to atmospherically and geographically conditions (Sağlam, 2006).

Lighting armatures and balasts are chosen from new generation products for energy saving purpose. System is controlled by fuzzy logic algorithms controller. Fuzzy inputs are determined by day light level, human motion information in room and accumulator voltage levels. Lighting level is kept at standard lighting level by the fuzzy logic controller using this input values at the work environment.

System energy is supplied from grid by the fuzzy logic controller (FLC) when the accumulator voltage level decreases below the determined level. Additionally, during this study, energy production graphics of photovoltaic panels are obtained for 1-year period.

2. The general configuration of the system

General configuration of system can be shown in Fig. 1. Illuminated indoor environment is the power electronic laboratory of the M.U. Technical Education Faculty Department of Electric Education, with dimensions 6.7 × 7 m. System has four 125 watt-peak (Wp) photovoltaic panels, one ISA data acquisition card, PC, DC–AC converter, two dry type, 12 V, 100 Ah capacity accumulators, charge regulator, 12 fluorescent lamps (each one 21 W) and designed electronic cards (Photovoltaic-Module, 2006; Castro et al., 2005; Farman et al., 2003; Linden and Reddy, 2001).

Fluorescent lamps are divided into three groups; Lamp Group 1 (LG1), Lamp Group 2 (LG2) and Lamp Group 3 (LG3). These groups are located in laboratory that the nearest group to windows is LG1, the middle group is LG2 and the far group is LG3.

2.1. Designed electronic cards

These cards are designed for controlling lamp groups, measuring lighting level and accumulator voltage level and providing isolation between PC and system.

2.1.1. Relay control card

Relay control card is designed with five single pole double throw (SPDT) relays which can be drived digitally (Fig. 2a). Grid and accumulator selection is made by first two relays and other three relays are used for controlling lamp groups (Sağlam, 2006).

2.1.2. Optic isolation card

Optic isolation card provides electrical isolation between PC and system, using five TLP521 optocoupler (Fig. 2b) (Sağlam, 2006).

2.1.3. Charge level control card

This card is designed for measuring accumulator voltage and generating different digital voltage level signals as "discharged" (<11 V), "charged" (11∼12 V), "charging" (12∼13 V) and "fully charged" (>13 V) (Fig. 2c). System is controlled via relay control card taking signals from this card (Sağlam, 2006; Alexandridis and Dounis, 2007; AEE Solar, 2000).

2.1.4. Light sensing circuit

Light sensing circuit is designed for measuring outside lighting level. Si photo diodes are used as light sensor.