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ANN Technique for Energy Management in a PV-Integrated Battery Energy Storage System

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ABSTRACT

The combination of Battery Energy Storage Systems (BESS) with Photovoltaic (PV) installations offers a possible solution to the intermittency and unpredictability of solar power supply. This research investigates the creation of an intelligent Energy Management System (EMS) that uses an Artificial Neural Network (ANN) approach to optimize the functioning of a PV-integrated BESS. The proposed ANN-based EMS is meant to precisely estimate solar power output and load demand, allowing for efficient energy storage and release, resulting in a balanced and stable power supply. The system's architecture and algorithms are implemented and tested using MATLAB/Simulink, demonstrating the potential of the ANN approach in enhancing the efficiency and reliability of PV-BESS configurations. The simulation findings show considerable gains in energy usage, reduced reliance on the grid, and better overall system sustainability. This work demonstrates the efficacy of ANN approaches in enhancing energy management strategies for renewable energy systems, hence leading to the widespread adoption of clean and sustainable energy solutions.

***KEYWORDS:** Energy Management System, Photovoltaic System, Battery Energy Storage System, Artificial Neural Network.*

1.INTRODUCTION

Microgrids are tiny, decentralised energy networks that may function independently of the larger power grid and other microgrids. According to the Microgrid Exchange Group of the United States Department of Energy, the following abilities are required: A microgrid is a tiny electrical grid that connects and controls loads as well as distributed energy resources within well defined geographic borders. A microgrid is essentially an autonomous grid within a larger grid. Microgrids may convert between grid-connected and island modes based on their needs.To satisfy its users' electrical power demands, a microgrid must have access to a generating source. Because of its age, the microgrid has frequently drawn electricity from fossil fuel sources situated "beyond the metre," such as gas-powered facilities. However, many of the microgrids that are now being created get their electrical supply from a combination of solar energy and battery storage due to the low cost of solar energy and the environmental benefits of switching away from fossil fuel-based power generation. To begin, it is vital to know that this is a type of local energy, which means that it caters to local clients. This is one of the primary distinctions between microgrids and the massive centralised grids that have supplied the majority of our country's power for the past century. Transmission and distribution lines connecting power facilities to large networks allow electricity to be sent across great distances. Long-distance power transmission is inefficient because some energy is lost along the route. This loss might be as much as 15% of the total. A microgrid avoids this inefficiency by generating power in close proximity to the customers it serves. Microgrids frequently have their power sources close by or within the structure itself, with the example of solar panels placed on the roof.

2. SOLAR ENERGY

2.1 Introduction

Solar cells are photovoltaic semiconductors that convert solar radiation into direct current (DC) electricity. Photovoltaic energy is created by solar panels made up of many individual cells, each of which includes a photovoltaic material. Silicon may be utilized in photovoltaics in a variety of ways, including monocrystalline, polycrystalline, amorphous, cadmium telluride, and copper indium selenide/sulfide [1]. However, amorphous silicon, another kind of silicon, is also beneficial. Other types of silicon, such as amorphous silicon, can also be used. Rising demand for solar and other renewable energy sources has resulted in considerable increases in solar cell and photovoltaic array manufacturing over the last several years. As of 2010, solar photovoltaics generated energy in over 100 countries and is the world's fastest growing power-generation technology, although it accounts for just a small percentage of the total worldwide power-generating capacity from all sources (4800 GW). Grid-connected photovoltaic From 2004 to 2009, system capacity increased by 60% to 21GW per year on average. Building Combined Photovoltaics, or BIPV for short, are systems that are either ground-mounted or, in certain cases, integrated with farming and grazing onto a building's roof or walls. Off-grid PV generates an additional 3-4 GW.

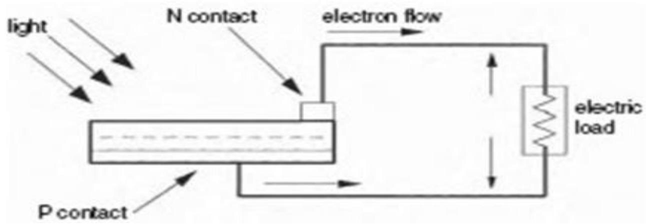

Fig 2.1: PV converts the photon energy into voltage across the p-n junction

Since the introduction of the first solar cells, technological breakthroughs and increased manufacturing efficiency have resulted in a continual decrease in the cost of photovoltaics. Positive feed-in rates for solar-generated power, as well as other financial incentives, have contributed to the global adoption of solar photovoltaics.

The photovoltaic effect is the process by which light causes a substance to generate a voltage. Despite their close proximity, the photovoltaic and photoelectric effects are distinct. When a substance is exposed to high-energy radiation, the photoelectric effect causes electrons to be released from its surface. What distinguishes the photovoltaic effect is that the generated electrons are moved across bands inside the material (from the valence to the conduction bands), resulting in a voltage rise between two electrodes. These cells were given their name since the sun is the most prevalent source of radiation used in photovoltaic applications. When exposed to light, P-n junction solar cells create current because the electric field in the depletion zone causes the excited electrons and remaining holes to move in opposing directions. Figure 2 clearly shows this tendency. Alexandre-Edmond Becquerel is credited with the discovery of the photovoltaic effect in 1839. In October 2010, Canada's 80-megawatt Sarnia Photovoltaic Power Plant was the world's largest PV power plant. There are numerous more significant PV power facilities, such as Spain's 60 MW Olmedilla Photovoltaic Park and Germany's 54 MW Strasskirchen Solar Park, Germany's

53 megawatts Lieberose Photovoltaic Park, Spain's 50 megawatts Puertollano Photovoltaic Park, Portugal's Moura Photovoltaic Park, and so on (40 MW in Germany).

2.1.1 In Buildings:

Photovoltaic arrays are often linked with buildings, either because they are installed on or next to the ground, or because they are incorporated into the design of the building itself. Arrays are often installed as an afterthought in preexisting buildings, often affixed to the existing roof or the existing walls. Alternatively, a cable may be run from an array located elsewhere and linked to the building in order to provide energy to the building. The vast majority of Germany's solar PV capacity, over 8,500 MW, was added to roofs that year.

2.1.2 In Transport:

Solar photovoltaics (PV) have been utilised for quite some time to generate electricity in space. Motive power generation from PV is uncommon in transportation applications, but its use as an auxiliary power source in vehicles like boats and automobiles is on the rise. While the power and usefulness of a standalone solar car are questionable, solar-charged vehicles can get you where you need to go. Solar-powered cars have already been shown out.

2.1.3 Standalone Devices:

Before approximately a decade ago, PV was often employed to power calculators and other novelty gadgets. These devices can now run for years without needing new batteries because to advancements in integrated circuits and low-power LCD screens, which has reduced the need for PV. However, in regions where grid energy is unaffordable owing to high connection prices, solar-powered remote fixed devices have lately gained appeal. There are a wide variety of applications for this technology, including water pumps, parking metres, emergency phones, garbage compactors, temporary traffic signs, and remote guard posts and signals.

2.1.4 Rural Electrification:

Since many rural villages in developing nations are more than five kilometres away from the nearest electricity line, photovoltaics have become more popular. Solar-powered LED lights have been distributed by an Indian government scheme to replace kerosene lamps in rural areas. The cost of a few months' supply of kerosene was compared to the cost of the solar lights. Cuba plans to provide solar electricity to remote areas that now lack access to the grid. While there is a clear justification for going solar in these areas due to the social costs and benefits, the lack of profitability may restrict such initiatives to purely altruistic ones.

2.1.5 Solar Roadways:

Since roadways are often unobstructed to the sun and represent nearly the proportion of land area required to replace other energy sources with solarpower, a 45 mile (72 km) length of roadway in Idaho is being used to investigate the idea of embedding solar panels into the road surface. As a result of its low environmental impact and low maintenance requirements, solar energy has recently emerged as the dominant technological platform. To improve energy efficiency, solar systems have recently been installed in highways.

2.1.6 Solar Power Satellites:

Spacecraft that harvest solar energy on a massive scale have been the focus of design studies for decades. Peter Glaser, formerly of Arthur D. Little Inc, initially proposed the idea in the 1960s; NASA conducted a lengthy series of technical and economic feasibility studies beginning in the 1970s; and the notion has lately seen renewed attention in the early 2000s. For such satellites, the problem of launch cost seems to be the most relevant issue from a practical economic aspect. Space-based assembly procedures still need to be developed, although this seems like a lesser hurdle than the initial investment. As the price of solar panels drops or their efficiency increases, these will go down.

2.2 Solar cell:

One way that sunlight may be converted into energy is via the use of a solar cell, which is a semiconductor device that exploits the photovoltaic effect. In the solar industry, solar modules are more usually referred to as solar panels, however they are really composed of cell assemblies. These solar modules generate solar electricity, which is one kind of renewable energy.

The PV potential originates from the disparity in the Fermi levels (chemical potentials) of the electrons in the two separated materials. When they're connected, a new thermodynamic equilibrium is established at the junction. Such a balance is possible only when the Fermi levels of the two substances are equivalent. The electrons flow from one material to another until the voltage difference between them is equal to the difference at the Fermi level. This potential is what powers the photocurrent in the PV system. Although the word is usually solely used to describe the process of harnessing solar electricity, photovoltaics is really the scientific study of how photovoltaic cells may be utilised to convert light into usable energy. Photovoltaic cells are those used when the light source isn't always the sun. These are used to either detect or quantify the intensity of light or other forms of electromagnetic radiation in the visible spectrum.

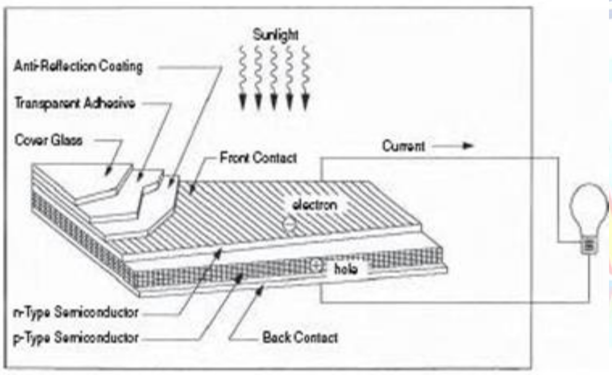

Fig 2.2: Basic construction of PV cell

Equivalent electrical circuit of a Battery:

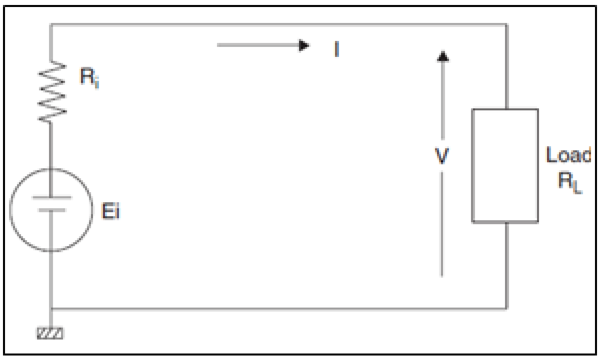

Fig 2.3: Equivalent electrical circuit of a Battery

II. PI CONTROLLER

PI controllers, or proportional-integral controllers, are a form of feedback controller used in control engineering to identify the optimal driving strategy for a plant. This kind of controller incorporates both the error, or the difference between the actual output and the goal value, and its integral into its calculations. One subset of PID controllers does not take into account the derivative (D) of the error signal.

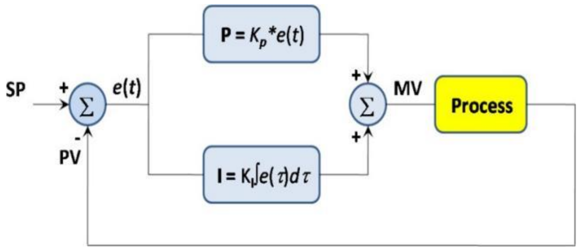

Fig.3.1: Block diagram of a PI controller

Integration of integral control action transforms the proportional controller into a high-order system. If Kp is very large, the control system may become unstable because the roots of the characteristic equation may have a positive real component. This is because it's possible that the roots of the characteristic equation will include a real-valued positive integer. When applied to a system subject to a wide range of inputs, proportional control tends to stabilise it, but integral control has the ability to significantly decrease or even eliminate steady-state error. There is a general trend toward less overshoot and faster reaction times as Ti increases.

3. ARTIFICIAL NEURAL NETWORKS

To put it simply, Artificial Neuronal Networks are streamlined computer representations of the brain's neuronal architecture. The brain is predominantly an experience learner. The findings suggest that tiny, low-power devices can address issues that modern computers cannot.

The use of brain models offers hope for a simpler way to developing technology solutions. These biologically-influenced computer techniques are likely to be the next big thing. Simple animal brains can perform things that computers cannot even begin to duplicate right now. Computers excel at mundane jobs such as managing an accounting system and computing complex calculations.

However, computers fail to recognize even the most fundamental patterns, let alone generalize prior acts into future behaviors.

Recent advances in biological research have provided promise for a first look into the workings of the mind in its natural condition. This study shows that the brain arranges information into patterns. Some of these patterns are highly detailed, allowing us to identify certain faces from many angles.

A new branch of computer science has emerged around the idea of storing data as patterns, applying those patterns to problems, and eventually obtaining a solution. Rather than utilizing normal programming, researchers in this field construct massively parallel networks and train them to solve issues. This field uses words like "behave," "respond," "self-organize," "learn," "generalize," and "forget" that differ significantly from the vocabulary of "conventional computing."

The word "neural network" (NN) refers to a mathematical or computer model based on biological brain networks, which separates it from a "artificial neural network" (ANN). It operates on a connectionist computing model and is made up of a network of artificial neurons.

During the learning phase of an ANN, the system often adapts its structure in response to incoming input from outside or within the network.

In a nutshell, neural networks are used to describe nonlinear statistical data. They are effective for identifying patterns in data and modeling complex relationships between inputs and outputs. A neural network, like the vast network of neurons in the human brain, consists of a collection of nodes that communicate with each other.

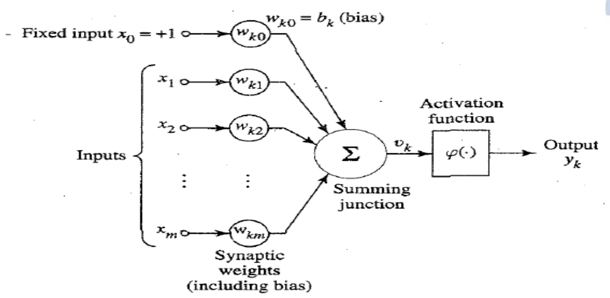

Fig 3.1: Artificial Neural Networks

4. SIMULATION RESULTS

Project Background

- A DC/DC boost converter is used in this project to connect the PV array to the DC bus.
- A bidirectional DC/DC converter regulates the charging and discharging of the batteries in the battery bank.
- For the purpose of linking the DC and AC systems, a central inverter has been set up.
- The DC load block often stands in for the many loads that connect to the DC bus.
- CAPMS chooses the operating modes of PV array & battery (charging, discharge mode) & delivers correct reference values to controllers based on PV output power, battery state of charge, battery power limit, and AC loads. In order to maintain a stable power supply, CAPMS will use one of many possible control strategies for the converters.

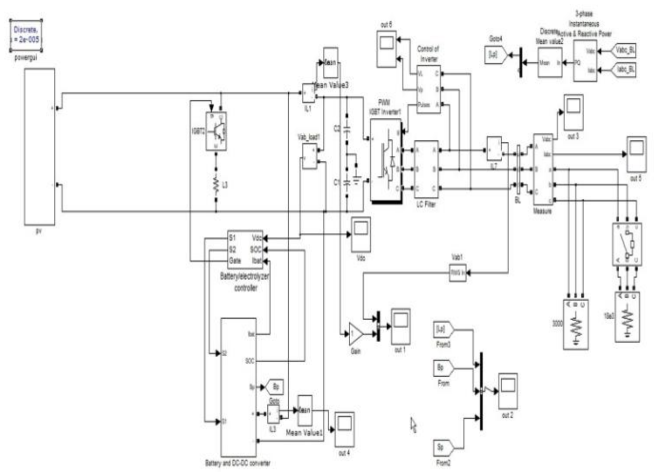

Fig.4.1Proposed Model

a) Case1:

Initialload-10000watt

Extraload - 4000watt

Battery Specifications:

1. 200volts,
2. 6.5AH
3. Nickel-Metal Hydrate Battery

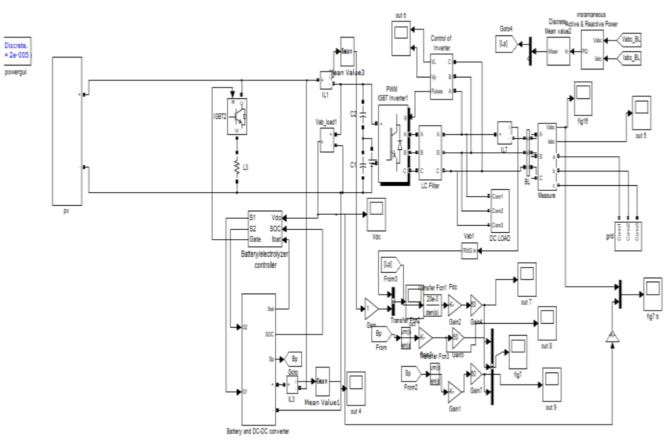

Fig 4.2 Simulation Model of Proposed System with ANN

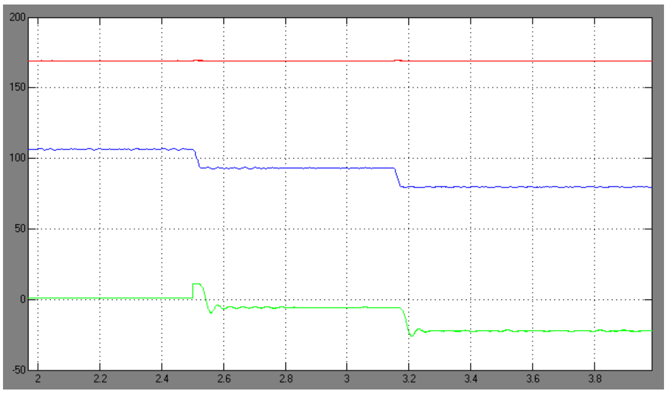

Fig4.3 Simulation result with PWM (PI) control

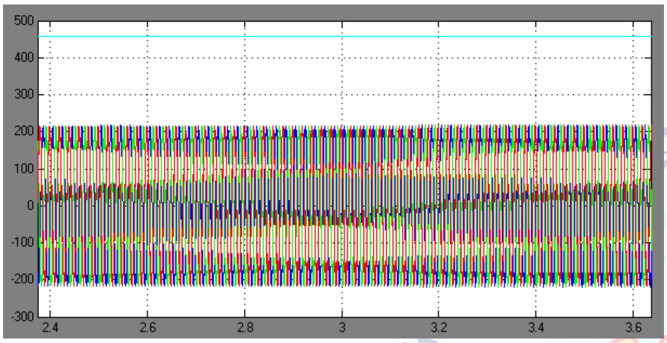

Fig 4.4 AC Line Voltage and Phase Voltage given by the inverter

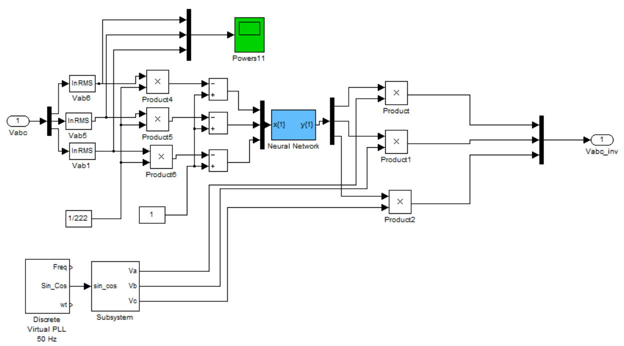

Fig 4.5 Inverter control with ANN control

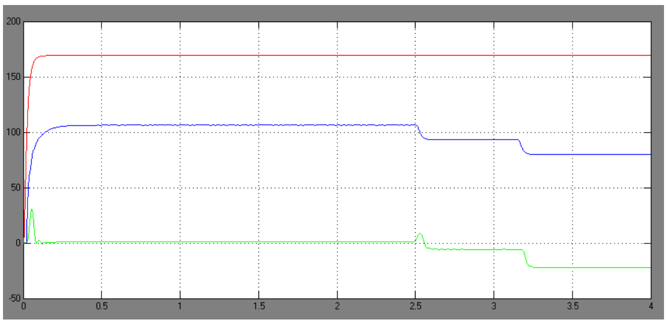

Fig 4.6 Simulation result with ANN control

5. CONCLUSION

In this paper, we provide a control and power management system for a PV battery system that operates in isolated mode and employs both DC and AC buses. When running in islanded mode, the CAPMS has total control over both the DC and AC bus. The presented CAPMS regulates power flows in converters of any size in an efficient and flexible manner. As an extra advantage, CAPMS maintains the system working smoothly even if the PV array fails due to a malfunction or power varies owing to unpredictable irradiance. The CAPMS optimises the reference values for each unit and delivers PWM (pulse width modulation) signals to the inverter and converter to control the hybrid system's power flow as well as the DC and AC bus voltages. The suggested CAPMS employs a tried-and-true approach, utilizing PI and ANN controllers. ANN controllers give better results than more conventional techniques.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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