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PHOTOVOLTAIC SYSTEM MODELLING AND OPTIMISATION IN PARTLY SHADED AND DYNAMIC ENVIRONMENTS

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Abstract:- The primary focus of this dissertation is the max power point tracking (MPPT) strategies to track PV systems in shaded, partially shaded, and changing irradiance conditions. In our initial studies on this topic we realized that analysis and simulation of MPPT systems relied heavily on the extraction of parameters and modeling of the photovoltaic (PV) cell modules, cells, and arrays. The scope of this thesis was expanded to include these subjects since PV system parameter extraction and modelling methods currently available have limitations.

The PV model is described in Chapter 1 and the rationale behind this study's topic. There are many approaches in the literature to modeling the PV cell modules, arrays, and MPPT methods are reviewed in Chapter 2. In the table, the efficiency of each method is evaluated and compared with the other. In chapter 3 we proposed a Chebyshev-based functional link neural network (CFLNN) for the purpose of modelling PV modules since methods currently used either show inadequate accuracy when variables derived from the PV array, or exhibit complex for their calculations. The proposed method increases modelling precision while also reducing the network-based model complexity through eliminating layering layers that are hidden from the design of the network. The current predictions using the two diode models and Multilayer Perceptron (MLP) methods of modelling are evaluated against those from the proposed method.

1 Introduction

In robotics, industrial automation, environmental monitoring, and other fields, distributed control is a widely used technology to monitor and regulate environmental conditions. Distributed control has been a popular control approach in recent years for managing the size and interaction of large-scale complicated control systems. The group of geographically dispersed hardware parts that make up Distributed Control Systems (DCS) are connected through a network. It consists of several subsystem components and a communication network for exchanging information. The DCS has shown effectiveness in information processing, monitoring, and control as the network of controllers is developed and created utilizing wired and/or wireless communication channels. They are autonomous control systems that operate for a specific objective under the master's supervision (Peter Kazanzides and Paul Thienphrapa 2008). The interest in modeling and managing large-scale systems has significantly expanded during the last two decades. Wireless communication channels or wired buses are used to manage the communication between the various subsystem components. Most obviously, a modular and extensible interfacing standard is required for the DCS since the subsystem components' unique interfaces limit extensibility and raise the cost of modifications. It is vital to control these components/nodes since the DCS relies on a variety of sensors and actuators to operate (Kim and Tran-Dang 2019).

The Software Architecture (SA) has a significant impact on how the DCS's components process information, are monitored, and are controlled. It offers an organized and abstract description of a system's overall structure. The high-level explanation of the DCS is given by SA in an abstract manner. Numerous architectural styles have been developed as a result of the enhanced development of software architecture designs to address a variety of software design problems. Different areas of software architecture, such as communication, deployment, domain, and structure, each have their own distinct styles. The aforementioned problems are eliminated by a suitable architectural style, which enhances partitioning. In accordance with user requirements, it may also be modified and used again for other purposes. Because of this, the hardware architecture of large-scale DCS consists of heterogeneous microcontroller systems, heterogeneous communication interfaces and channels, sensors, and actuators that are monitored and controlled using the proper software architecture style (Veli-Pekka Eloranta et al. 2009, Javier Gamez Garcia et al. 2009).

2 Litreature Survey

A sophisticated robotic system must be capable of capturing, analyzing, and transmitting all discovered information through the sensor, according to Gutemberg et al. (2021). Robotic architecture is needed to do this. Obstacles to designing robotic architecture include the complexity of robotic systems and the wide diversity of hardware. To deal with this complexity, a distributed hardware and software architecture is developed using communication interfaces. The main objectives are to operate distributed robots and develop the communication interfaces that will connect them to the control base station. Using data that has been detected, the robotic system is capable of making judgments. Before taking the right action, it processes the information it has received using computational models, database mapping, and other techniques. Sarnali et al. (2019) created the Universal Robot Bus Architecture (URB), which allows the robot to operate in real-time for data collection using RS232 and I2C as the uplink and downlink, respectively. The URB is a modular real-time Field-bus architecture for autonomous mobile robotic systems that makes it simpler to combine a range of sensors, actuators, and computation units. It features a two-tiered structure and facilitates the system's varied integration of communication protocols. As a consequence, a wide range of hardware and software components with various communication channels and functionalities may be combined.

Diego P. Losada et al. (2019) have discussed a CAN-based distributed system that combines sensors, actuators, and hardware controllers of the DCS used in a mobile robot platform. The combination of these hardware elements yields a flexible and dependable platform that may be used to many mobile robot platforms. The development of modular architecture for the incorporation of sensors and distributed hardware control is its main objective. Bus-based design allows for the functional system to be easily connected to and disengaged from any hardware module.

J. K.R. Sastry et al. (2022) presented a distinctive distributed embedded system using the CAN protocol. Its foundation is a network of diverse microcontrollers. It is used to monitor and control reactor temperature in nuclear reactor systems. The CAN-based network used for the application has a single master and four slaves. Every heterogeneous distributed embedded system needs a different communication system architecture, so it's important to find mechanisms and methods that take these various communication-related factors into account. These factors include addressing, configuration, transmission, reception, arbitration, synchronization, error detection and control, etc. Depending on the application, data flow control varies; in this example, the data packet and its flow are meant to monitor and control the temperatures within a nuclear reactor system. Thanks to communication between the master and slave, signals may be sent a distance of 1 KM.

3 Methododlogy

Power production greatly benefits from the use of sustainable and renewable energy sources. Since solar power is a clean, environmentally friendly, widely accessible, and limitless source of energy, it has gained popularity as a method of generating electricity. Because it offers a DC output, the solar PV system helps to meet the growing need for DC electricity. Additionally, it supports the idea of a distributed generation (DG) DC micro-grid.

The growth of technology in the fields of energy and computer methods, together with the availability of inexhaustible resources, spurs intense research for better, more efficient, and environmentally friendly power plants. The solar PV system has developed into an affordable, low-maintenance, and low- to medium-power source in rural regions. Most of the power source is converted into PV-generated systems.

They are growing in power because of the constant reduction in the cost of PV modules as well as the improvement in the efficiency.

The solar PV module demonstrates two key traits. Many studies have been conducted worldwide to make the most of I-V and P-V characteristics in order to get the maximum performance out of any solar panel, as stated in the preceding chapter. However, in addition to dynamic climatic circumstances, the total efficiency of solar production also takes into account the influence of the solar array system, the applied regulator system (DC/DC or DC/AC converter), the cabling utilized for connections, and the linked batteries. As a result, a technique for distant DC Micro-Grid with a self-sufficient, effective DC power supply is required for use in distant locations.

Since their development, the primary challenge with solar panels has been their viability. Initially, the efficiency of the panel was only approximately 1%; now, panels with an efficiency of up to 22% are available. Since the invention of the solar panel, industrial output has expanded steadily, and thanks to technical advancements, markets for solar PV generating are growing.

Due to the limitations of cyclic time dependence, solar PV systems have energy storage devices like batteries installed. These devices produce electricity when there is no solar radiation and when there is a change in weather or partial shading. Solar PV systems are becoming more widely used and more reasonably priced thanks to extensive research and improvements in energy storage technologies. The idea of a DC Micro-Grid made up of solar PV and batteries is becoming increasingly practical and cost-effective for local DC load types. The level of penetration for PV generators for medium and small isolated systems is set by the system's planner in conjunction with the array's dimensions and the capacity expansion for future use, as well as demand forecasts. Modeling analyses and methodologies are outlined in the next section.

The Li-Ion battery charging method was covered in the part above, and a mathematical model was developed for simulation purposes. With the use of equations and a block diagram created in the mathematical model, a MATLAB/SIMULINK simulation model is produced in this part. The suggested CT-CV technique is determined to be superior in comparison to efficiency and performance of the battery since the traditional way of charging Li-Ion batteries is the CC-CV method and taking the temperature limit into consideration.

Consequently, a simulation model for adaptive charging is being created, as shown in the stages below. In the CT-CV methodology, the battery is charged while the temperature is kept at a reference level, and the charging current is controlled using an exponential function, which shortens the total charging time in comparison to the traditional method. In the MATLAB/SIMULINK environment, simulation models for the CC-CV and CT-CV charging approaches are created, and an adaptive charging method is created employing both charging strategies as and when necessary.

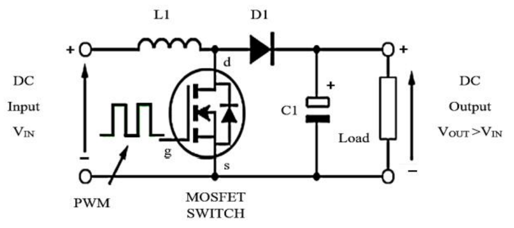

Figure 3.1: Circuit diagram of boost converter.

4 Experiments & Results

Buck converter based on N channel is shown in Figure 3.6. The MOSFET source terminal is unconnected from the ground circuit and is floating. As a result, the correct circuitry needed to activate the MOSFET is known as high-side drivers. Due to the floating switch being turned off, it is more difficult than low side drivers. The source terminal of a MOSFET is uncommon in terms of voltage source. Kirchhoff's voltage law is used to explain the switching issue in the buck converter loop.

Environmentally friendly energy sources including solar, wind, and water have gained popularity as a clean alternative to traditional energy sources [1-2]. Due to its simplicity and constant accessibility at no cost, solar energy is typically the most advantageous of all these green energy sources [3–4]. The proficiency of solar cell materials, however, is what determines how well solar energy can be captured [2,5]. Additionally, the solar panel's output power is impacted by the fast variations in solar irradiation and temperature, which reduces its capacity to transmit electricity to the load [4–9]. In situations when there is partial or complete shade, this problem becomes more important [5-7]. Maximum Power Point (MPP), as seen in Fig. 1.1 [2-7], is the point at which the solar panel provides the load with the most power achievable for a certain amount of voltage or current. The operating point oscillates around MPP due to the changing climatic circumstances, which has an impact on the ideal, optimal power supply to the load. The cost of solar energy harvesting per watt increases due to all of these factors [4–8].

Tests for the effectiveness of heat conductivity NPCM and PCM with various mass levels are shown on Figure 4.1. Likely it was predicted, the enhancement in thermal conductivity of PCM was significantly enhanced because of the inclusion of nano particles in the PCM. In comparison with PCM which has the most significant rise of thermal conductivity occurred between 111, and 69.0 percent, when nanomaterial Al2O3 and SiO2 were added with mass fractions as high as 20.0wt. percent. Results show that Al2O3 Nanoparticles with a weight of 20.0wt. percent is a conductor of 0.422w/m0C is noteworthy because it is an increase of 42% over SiO2 with the same concentration of mass. Also, it is observed that the conductivity of the thermal properties of NPCM created from Al2O3 as well as SiO2 rises approximately the same with the addition of 2 or five percent nanomaterial of either, and an increase of 2-7%. The heat conductivity Al2O3 and NPCM has been observed to rise significantly after adding nanomaterials with similar properties at 10 15, 15 and 20wt. percent. Table 4.1 provides PCM as well as NPCM thermal conductivity data as well as the increase in the temperature conductivity NPCM in comparison to PCM. Table 4.2 provides the theoretical and experimental the theoretical conductivity of the NPCM.

Table 4.1 Conductivity in thermal of PCM and the NPCM

Material	Mass Concentration (wt.%)	Thermal Conductivity (W/m ^{0}C)	Thermal Conductivity Increment (%)
PCM	0%	0.2	0
	2%	0.221	10.5
	5%	0.237	18.5
SNPCM	10%	0.268	34
	15%	0.301	50.75
	20%	0.338	69
	2%	0.226	13
	5%	0.252	26
ANPCM	10%	0.3	50
	15%	0.356	78
	20%	0.422	111

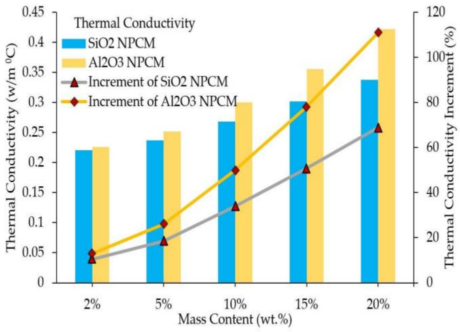

Figure 4.1 NPCM and PCM thermal conductivity

Table 4.2 Experimental and theoretical thermal conductivity of SNPCM and ANPCM

Nano particles Mass Fraction in PCM	Maxwell Garnett Model	Maxwell Eucken Model	Bruggeman Model	EMT model	Kingery Model	Experimental Results of SiO_2 NPCM	Experimental Results of Al2O3 NPCM
2%	0.207	0.234	0.235	0.219	0.223	0.22	0.226
5%	0.219	0.249	0.285	0.250	0.259	0.23	0.252
10%	0.240	0.275	0.360	0.302	0.318	0.26	0.3
15%	0.262	0.304	0.425	0.355	0.377	0.30	0.356
20%	0.286	0.335	0.481	0.411	0.436	0.33	0.422

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