A Solar-Powered Induction Motor with Maximum Power Point Tracking Implemented On a Low-Cost PIC-Microcontroller

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ABSTRACT: This dissertation presents the design, simulation and analysis of a Solar powered Battery Charger & Induction Motor using MPPT method. Fossil fuels are a relatively short-term energy source; consequently, the uses of alternative sources such as solar energy are becoming more wide spread. To make solar energy more viable, the efficiency of solar panel systems must be maximized. A feasible approach to maximizing the efficiency of solar panel systems is sun tracking. Proposed in this report is a system that is solar panel that is directed towards the sun-rays so that more and more amount of sun-rays are absorbed by Solar cells which then converts them into electricity.
The compactness of the proposed solar system enables it to be mounted onto the wall. The sunrays are absorbed by the surface of the photovoltaic panel. The PV panel absorbs more & more rays coming from sun during the day (mostly in summer). A computer model of the solar MPPT system is modelled using MATLAB/Simulink. The efficiency over the fixed solar panel, the power generated and the types of PV systems to achieve the required level of efficiency can be determined before actual implementation. The experimental testing shows some agreement with the simulation results.

KEYWORDS: PV ARRAY, MPP, MPPT, PIC, LCD, FLC, etc.

I. INTRODUCTION

As the range of applications for solar energy increases, so does the need for improved materials and methods used to harness this power source. There are several factors that affect the efficiency of the collection process. Major influences on overall efficiency include solar cell efficiency, intensity of source radiation and storage techniques. The materials used in solar cell manufacturing limit the efficiency of a solar cell. This makes it particularly difficult to make considerable improvements in the performance of the cell, and hence restricts the efficiency of the overall collection process. Therefore, the most attainable method of improving the performance of solar power collection is to increase the mean intensity of radiation received from the source. There are three major approaches for maximizing power extraction in medium and large scale systems. They are sun tracking, maximum power point tracking or both.

In this dissertation, the development of a maximum power point tracking for photovoltaic systems has been presented. The experimental results obviously show that the fuzzy logic control we proposed can give significantly faster tracking speed than the conventional Hill-Climbing method. Furthermore, the power fluctuation in steady state condition is substantially mitigated. We have demonstrated that the proposed algorithm can be easily implemented on a low-cost PIC16F87 RISC microcontroller-based system to form a high performance solar-powered battery charging system. Although without any external measuring unit, the maximum power point of the solar cell can be efficiently tracked with fast and smooth reaction to the environment changes. The efficiency of the whole system is well above 90%.

Most photovoltaic solar panels are fitted in a fixed location- for example on the sloping roof of a house, or on framework fixed to the ground. Since the sun moves across the sky though the day, this is far from an ideal solution. Solar panels are usually set up to be in full direct sunshine at the middle of the day facing South in the Northern Hemisphere, or North in the Southern Hemisphere. Therefore morning and evening sunlight hits the panels at an acute angle reducing the total amount of electricity which can be generated each day.

I.   **Solar Power in India :** In July 2009, India unveiled about US$19 billion plant to produce 20 GW of solar power by 2020. Under the plan, the use of solar-powered equipment and applications would be made compulsory in all government buildings, as well as hospitals and hotels. On November 18, 2009, it was reported that India was ready to launch its National Solar Mission under the National Action Plan on Climate Change, with plans to generate 1,000 MW of power by 2013.

II.   OBJECTIVES OF PAPER

In this dissertation work, following objectives will be achieved.
i.   Use of renewable energy source for power generation & also to avoid pollution
ii.   Modeling of PV solar system
iii.   Simulate the PV solar system in MATLAB/SIMULINK
iv.   Design the Battery & Inverter system that can run AC load
v.   Use of Maximum power point tracking MPPT to improve solar panel efficiency
vi.   Design low cost solar panel that is compatible for users

III.   DESIGN & WORKING OF SOLAR POWERED BATTERY CHARGER & INDUCTION MOTOR

a.   Mechanical System
After the solar panels and other components were selected, the overall structural design of the of project made. The structure was prepared as shown in fig. 1.1. There is 100W polycrystalline solar panel, boost converter, PIC micro-controller, battery & pump motor.
All the accessories are assembled as shown in below figure 1.1

b.   Electrical System
The overall mechanical and electrical subsystems were integrated into the solar power system as shown in Fig. 1.2 The detailed design of the circuitry could be found in the block diagram of the solar power system consists of mostly electrical components. This system consists of the PV cells, the charge controller and the lead-acid battery. Other subsystems such as the PIC microcontroller boost converter, battery. The PV cells absorb the sunrays and convert these into electricity. The electrical energy is then stored in the lead-acid battery that is later used to power the respective components.
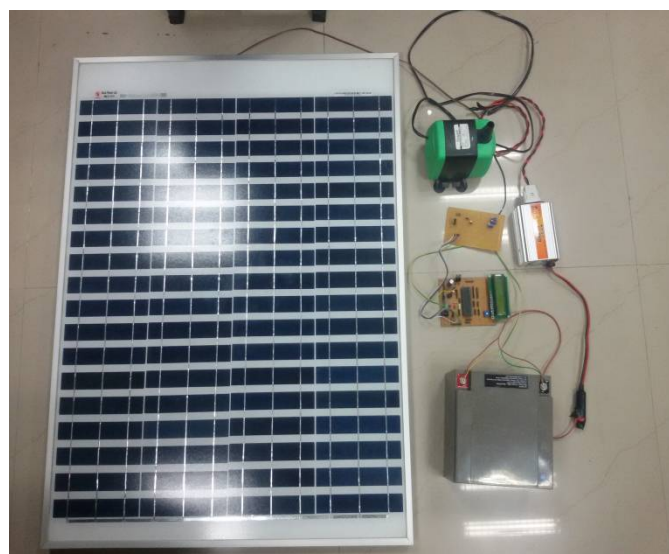

Fig. 1.1: Solar powered battery charger & induction motor

The project consists of various units viz., power supply, Microcontroller PIC16F877A, solar panel, 16X2 LCD, boost converter, battery, battery charger unit, inverter and induction motor. Solar panel with the rating 12V, 8A will be

connected to circuit as a source. The voltage will be monitored through PIC microcontroller using Analog to Digital channel. Corresponding voltage value will be display on the LCD interfaced with microcontroller. The same supply from solar panels will be given to 12 Volt batteries which are supplying power to inverter unit to give to induction motor. To give solar supply to battery, we have used boost converter. With the PWM of microcontroller, circuit is designed to boost solar voltage. We have used induction motor of 40W to be driven. To invert the battery supply into AC, we have used inverter circuit of 150W.

c.   Modes of operation

There are three modes of operation of working the induction motor. They are namely: Fully solar power operated, Fully batery operated and partly solar & partly battery operated motor. In fully solar power operation mode, solar panel is placed directly in sunrays and in this mode the electricity generated directly from PV panel is used to drive motor through battery & inverter. In second mode of operation the battery is used to store the charge (electricity) in it using sunrays or battery can also be charged from electric supply. Using the energy stored in battery is then send to inverter which in turn drives the motor. Third mode the motor is run using partly solar power & partly battery voltage.

IV.   PRINCIPLE OF MAXIMUM POWER POINT TRACKING CONTROL

The photovoltaic module operation de pends strongly on the load characteristics, (Fig. 2 and 3) to which it is connected. Indeed, for a load, with an internal resistance Ri, the optimal adaptation occurs only at one particular operating point, called Maximum Power Point (MPP) and noted in our case P max.

Thus, when a direct connection is carried out between the source and the load, (Fig. 1), the output of the PV module is seldom maximum and the operating point is not optimal.

To overcome this problem, it is necessary to add an adaptation device, MPPT controller with a DC-DC converter, between the source and the load, (Fig. 3). So, the MPPT controller is also required to track the new modified maximum power point in its corresponding curve.
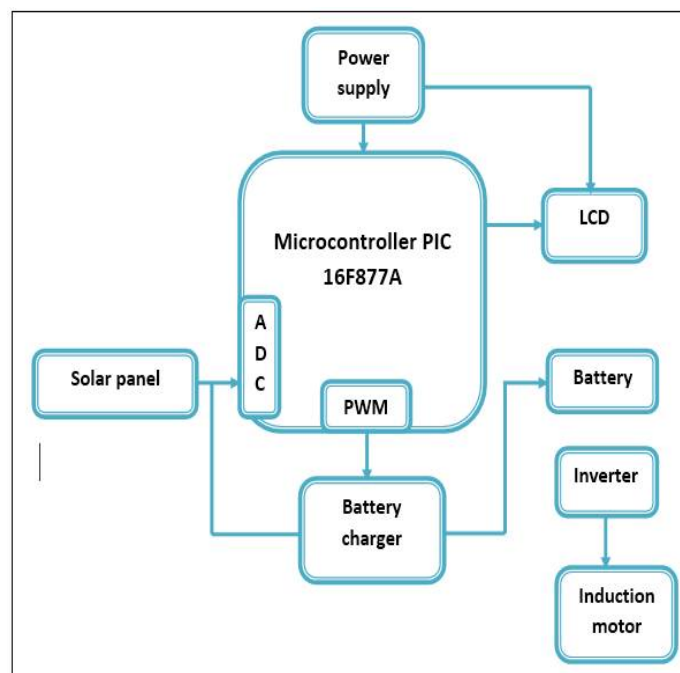

Fig. 1.2: Block diagram of the solar powered induction motor

Fig. 1: Current-voltage characteristic of a PV module

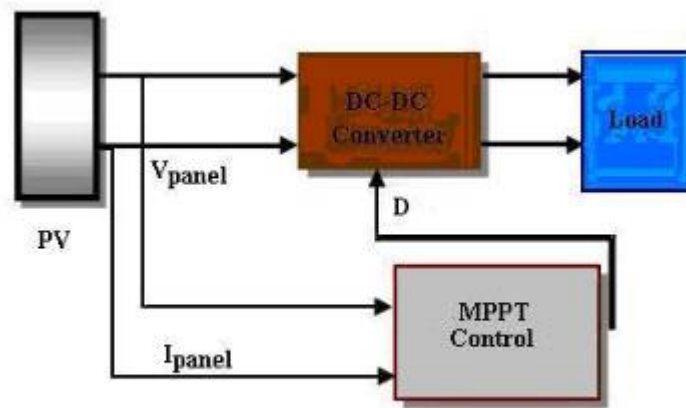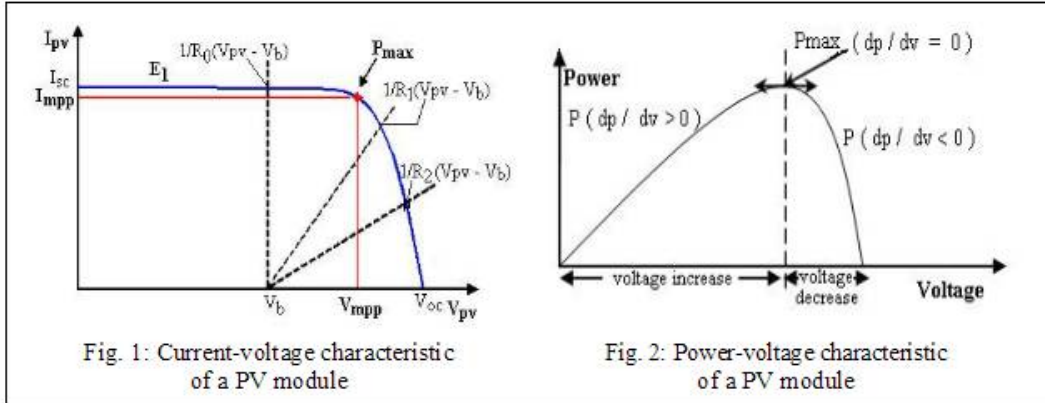Fig. 2: Power-voltage characteristic of a PV module

Fig 3: Photovoltaic system

V.   FUZZY LOGIC MPPT CONTROLLER

Recently fuzzy logic controllers have been introduced in the tracking of the MPP in PV systems. They have the advantage to be robust and relatively simple to design as they do not require the knowledge of the exact model. They do require in the other hand the complete knowledge of the operation of the PV system by the designer.
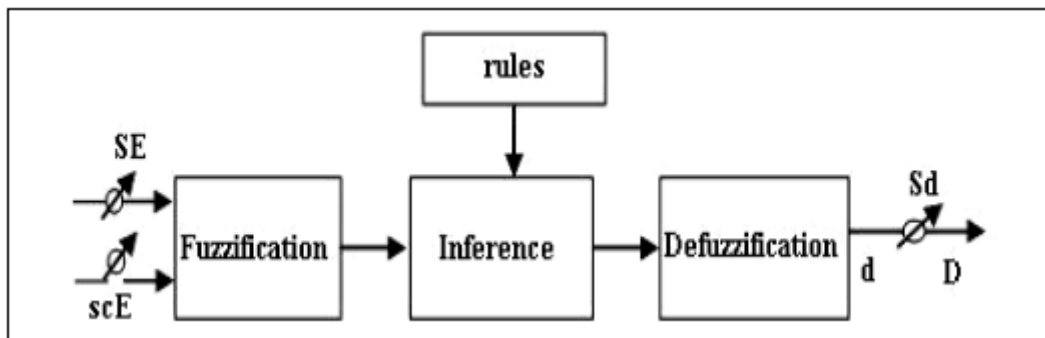

Fig. 1.3: General diagram of a fuzzy controller

The proposed FL MPPT Controller, shown in Figure 1.3, has two inputs and one output. The two FLC input variables are the error E and change of error CE at sampled times k defined by

$$E(k) = \frac{P_{ph}(k) - P_{ph}(k-1)}{V_{ph}(k) - V_{ph}(k-1)}$$

$$CE(k) = E(k) - E(k-1)$$

where $P_{ph}(k)$ is the instant power of the photovoltaic generator.

The input E(k) shows if the load operation point at the instant k is located on the left or on the right of the maximum power point on the PV characteristic, while the input CE(k) expresses the moving direction of this point.

VI.   RESULTS

a.   Experimental Results

Table 5.1: Solar output of PV panel in fixed mode

Time of the day	Voltage (V)	Current (A)	Power (W)
9 am	13.47	0.44	5.93
10 am	15.25	0.45	6.86
11 am	15.45	0.46	7.11
12 pm	16.11	0.51	8.22
1 pm	18.11	0.57	10.32
2 pm	16.23	0.53	8.60
3 pm	15.78	0.49	7.73
4 pm	13.32	0.43	5.73
5 pm	12.04	0.33	3.97

In order to validate the proposed modelling, it was necessary to compare the experiment results for the fixed panel. To obtain this data, simple experiments were performed. The setups were installed on building roof top. The open-circuit voltage and the current readings were recorded using a multi-meter connected to the solar cells. The readings are as shown in Table 5.1 and Table 5.2.

The graphical representation of current and power output of both the fixed PV panel and the tracking PV panel against day time is shown in fig. 5.1 and fig. 5.2. It illustrates improvement in efficiency gained with using solar tracking system.
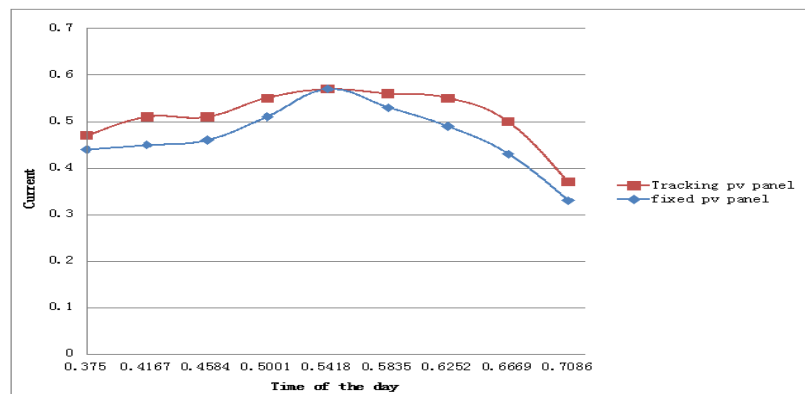

Fig 5.1: Output current of fixed PV panel and tracking PV panel

From the graph, it can be seen that solar intensity increases with day time to maximum at 1pm and then starts decreasing. Some fluctuations notable in the graph were as a result of some cloudy sky and abnormal atmospheric condition. The percentage increase in solar power output gained is tabulated below.

The table 5.3 shows the percentage power increase that is obtained from PV panels. It is seen that at a point the power output of the fixed solar panel are ok. This is as a result of panel facing the sun.
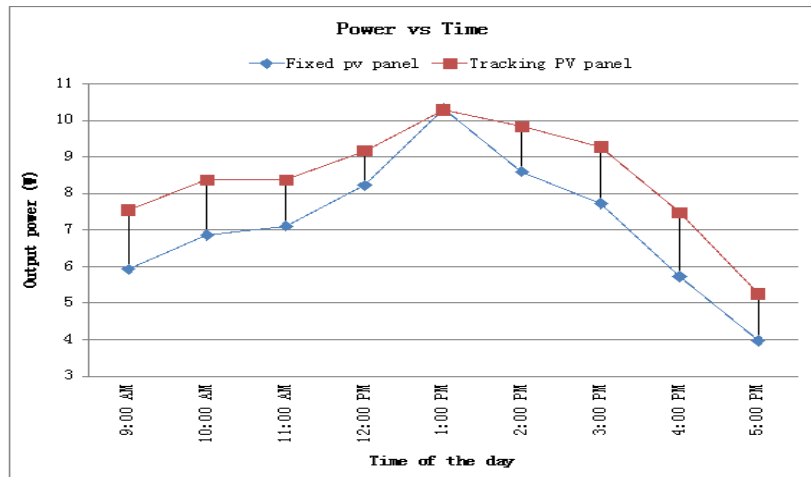

Fig 5.2: Output power of fixed PV panel

Power obtained by PV panel	Percentage gain
5.93	27.32%
6.86	22.01%
7.11	17.72%
8.22	11.56%
10.32	0%
8.60	14.30%
7.73	20.05%
5.73	30.54%
3.97	32.24%

Table 5.3: Percentage increase gained

b.   Simulation Results

The simulation results of the solar tracker using the Simulink are shown in Fig. below. As observed from the plots, the solar tracker is able to follow the sun angle. In the plot, the smart solar tracker produces a higher current output as compared to the static PV panel. The other part of the graph shows the state of the charge during the simulation. As seen in the battery voltage, the Switch A was deactivated when the maximum allowable voltage of 12.95V reached. The switch B was always connected during the entire duration (in charging mode).
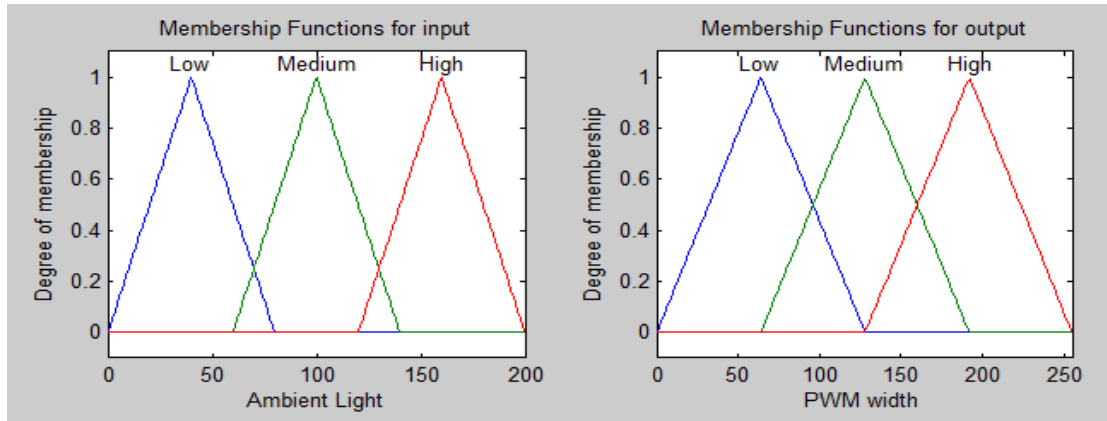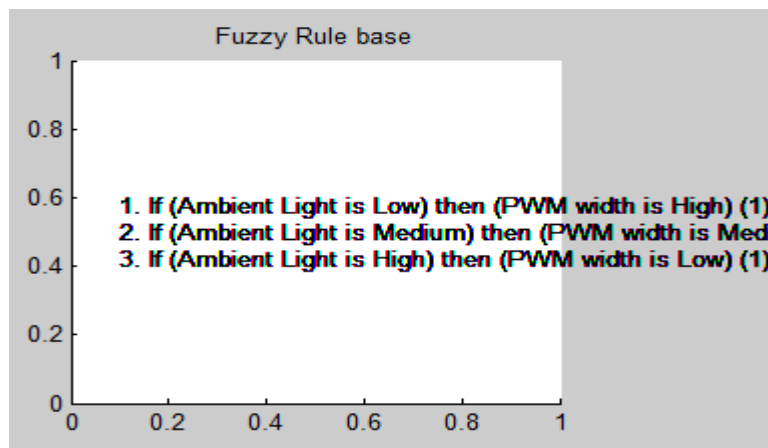
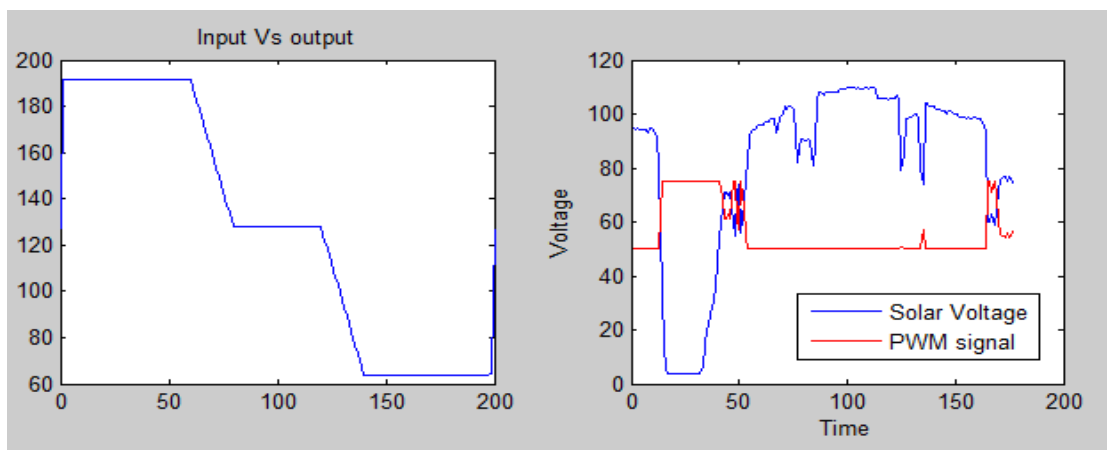Fig. 5.3: Ambient light & PWM width graphs

Fig. 5.4: Fuzzy rule base

Fig. 5.5: Output of solar voltage Vs. PWM signal

The simulated current over the day was quite close to the actual results obtained. There was some slight deviation during the noon and evening period due to the modelling of the actual irradiance.

The output power of the smart tracker was compared with the fixed panel design in order to determine the efficiency of the solar tracker system. As expected the overall power (or the efficiency) generated by the tracking panel is higher than that of the static panel. Here, the efficiency refers to the ratio of difference between the sum of smart tracker and

the fixed panel power to the sum of fixed panel power over the period of interest. The efficiency (obtain from experiment results) is around 20%. As compared to various the solar trackers as seen the average efficiency is around 12-15% and hence, the proposed design is slightly higher and comparable to the existing design.

VII.   CONCLUSION

In this dissertation, MATLAB/SIMULINK model and hardware of an solar radiation system was developed.The microcontroller based circuit is used in this system with a minimum number of components to run the Pump Induction motor.

After examining the information obtained in the data table section and in plotted graph, It has been shown that the fixed panel system gives good eficiency using renewable energy sources. It can be said that the proposed system is a feasible method of maximizing the light energy received from sun. This is an efficient system for solar energy collection.

The method implemented in this project is simple, easy to maintain and requires no technical attention for its operation. The software developed for this work can be used outside the mechanical part, thus it is flexible for future modification. The solar module gives good efficiency. Hence implementation of this technique in building solar systems will greatly improve utility satisfaction.The experimental results show a similar behavior in efficiency and the current output when compared them with the simulation results.

VIII.   SCOPE FOR FUTURE WORK

To improve the flexibility, an **automatic solar tracker system** can be modelled with weather conditions such as wind and raindrop. Tracking the sun irradiance in an ideal condition would involve no disturbances on the system. But in practice, factors such as external force like wind and rain moves the tracker away from its position. It is therefore vital for the solar tracker to be able to track the sun throughout the daytime. The external disturbances such as wind loading and raindrop model provide an insight to the impact of the current consumption on the model of the solar tracker before actual implementation.

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