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Remote Controlled Solar Home Lighting System ForSenior Citizen.

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ABSTRACT:
Renewable energy systems are inevitable due to their advantages over non-renewable energy systems. Solar renewable energy systems consist of very few sub-systems and hence more attractive. It has been observed that the many senior citizens are keener in these systems due to their simple operation, easy maintenance and clean energy. The advanced microcontrollers, wireless technologies make these systems more versatile in terms of control and operation. The infrared (IR) technology is the basic technology used to operate many electrical and electronic systems wirelessly. The paper presents the solar powered, remote controlled home lighting system for senior and differently abled citizen. The papers deal with the design and development of a complete wireless home lighting system.
Key Words: Renewable energy, Solar, IR, Irradiation, Electrical, Citizen.

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I. INTRODUCTION

India has vast solar energy base of 5000 Trillian kWh per year. According to global study, most parts of India receive 3-4 kWh/m^2/day. Therefore, the efforts are on to harvest solar energy to reduce the pollution level of the environment. The cost per solar cell have decreased substantially, which led to the large production of solar panels for various applications. The major applications of solar energy are, automotive, home lighting, agriculture and so on.

Solar powered energy systems are now popular due to their ability to produce clean energy, reduced cell cost, low maintenance cost. The conversion efficiency of the solar power system largely depends upon the solar irradiance. Solar irradiance is the output of the light energy from the entire sun. The amount of solar irradiation reaching the earth depends upon the terrain, season, atmospheric conditions.

The major factors which govern the amount of irradiance received at the surface of the earth/location are angle of incidence, duration of sunshine and many more. In order to increase the efficiency of the solar powered systems, many techniques are employed in the design. To utilize the solar energy to the extent possible, the energy storage systems must be included in the solar system. The storage device is a battery which need to be charged to use the stored energy during night. Many techniques are employed to charge the battery. These techniques are pulse width modulation (PWM), maximum power point (MPPT) etc. These systems are the route to rural electrification and hence the overall growth of the country. In order to increase the gross domestic product (GDP) of the country, the standard of living, product availability has to have constant & steady improvement across the country. To aid the growth of the GDP, it is important to achieve energy independency. Energy independency can be achieved by migrating to alternate energy resource like, Solar, Wind, Biomass etc. The amount energy available from the Solar resource is much more and clean as indicated in previous paragraphs of the paper. An effort is made to highlight the issues, methods and conservation of energy in this paper.

The paper is arranged in such a way that the section 2 describes the related work done in the past, section 3 details the problem overview, section 4 deals with the proposed work, section 5 presents the simulation, experimental models results and analysis of the proposed work and section 6 presents the conclusion.

II. RELATED WORK

Rural electrification was not considered as the important factor in the growth of the country in the past. Though the importance was given to the food & shelter but the villages were deprived of electricity. Electricity is still a distant dream in many rural areas due to lack of infrastructure, technology even today [1]. Due to depletion and negative impact of fossil fuel energy resources, alternative energy resources are gaining momentum. The various technologies and methods available to harvest the renewable energy are plenty. The present scenario of power available in India and mechanism to harvest the renewable energy have been discussed in [2].

The cost analysis of few fossil fuel-based electricity generation is discussed in [3]. Study indicates that the cost per unit of electrical energy generated from the fossil fuel resources much costlier, and expected to become nonexistent soon. Therefore, the study suggests to harness the solar renewable energy resource for residential purpose.

The importance of rural electrification, the major hurdles, in achieving the energy independency is dealt in [4]. The prospects of utilizing the solar home lighting system in Bangladesh and other developing countries has been discussed. The paper presents that the only possible solution to achieve energy independency is through renewable energy resources.

In [5], the MPPT method is adopted to harvest the solar energy along with DC-DC converter throughout the clear day. The performance of the system depends upon various operating conditions when MPPT is utilized in the system development.

The response and performance study of MPPT algorithms for the better extraction of the solar energy depends on the operating conditions, system design criteria [6] to [10]. It has been indicated that perturb and observation (P & O MPPT) has a better response to varying operating conditions of the solar system [11] to [15].

The major problem involved in harvesting the solar energy is that the drift and instability of operating point of power conversion technique [16] to [18]. From the literature it is clear that many techniques have been employed to improves the conversion of solar energy into useful electrical energy. The paper suggests, the other ways of conserving the energy with protype.

III. PROBLEM OVERVIEW

The literature survey in section (2), indicates that the solar home lighting system design requires special care about the operating point, monitoring various parameters, control to ensure the reliable and long utilization of the system.

The performance of the solar panels can be understood from their I-V and P-V characteristics. The performance curves of solar cell/panels are obtained under standard operating conditions including the temperature of the environment. The temperature variation has the impact on the performance of the panles while converting solar energy into electrical energy. The typical I-V & P-V characteristics of panel are shown in Figure 1.

Operating point of the solar panel plays a major role in energy conversion process. This could be easily handled by adopting to MPPT techniques in the energy conversion process. The MPPT techniques ensure the proper operating point such that the maximum voltage (V_{MPP}), maximum current (I_{MPP}) and hence the maximum power (P_{MPP}) is harvested from a panel.

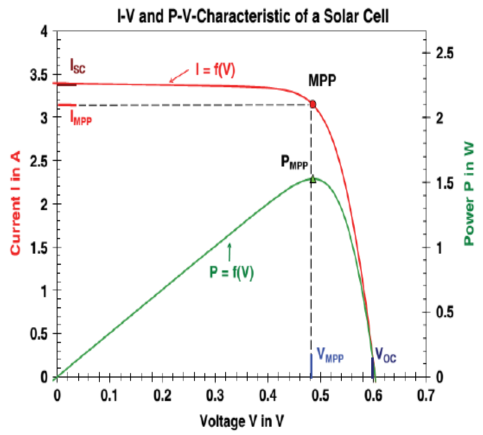

Figure.1: (a) I–V and (b) P –V characteristics of PV panel at different environmental conditions [19]

The performance of the solar home lighting system (SHS), is guaranteed only when all the sub systems work efficiently. The solar home lighting systems consists of battery an energy storage system, solar panel to convert irradiance to electricity, a charge controller to charge the battery and a control system to avoid deep discharge of battery.

The efficiency of the solar lighting system can be increased by implementing a monitor and control features within the charge controller. The monitor and control subsystem of the main controller continuously monitors the charging, discharging process of battery from a solar input, and initiates necessary actions according to the sensed parameters. Many solar home lighting systems lack in terms of monitor and control features there by compromising on the efficiency of the system by 25%.

IV. PROPOSED SYSTEM

The block diagram of the proposed solar home lighting system is shown in Figure 2.

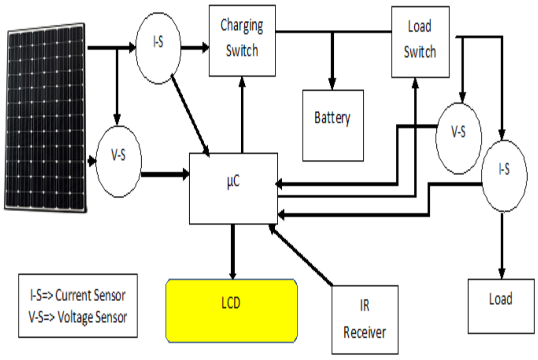

Figure 2: Block diagram of Solar Home Lighting System (SHLS).

Based on the discussion in section (3), the proposed system has been designed with:

i. MPPT algorithm,
ii. 3-Step charging process
iii. Over charge and deep discharge control,
iv. IR based Electrical appliance control,
v. The input and output power monitor and display,

The Perturb & Observe MPPT algorithm is used to harvest maximum power from the solar by tracking the operating point continuously. The P & O algorithm is depicted in Figure 3.

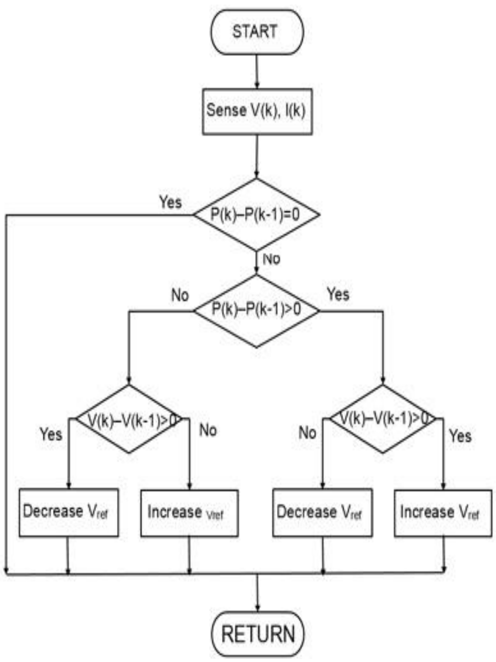

Figure 3 P & O algorithm

The typical IV and PV curves of the solar panel are shown in figure 4:

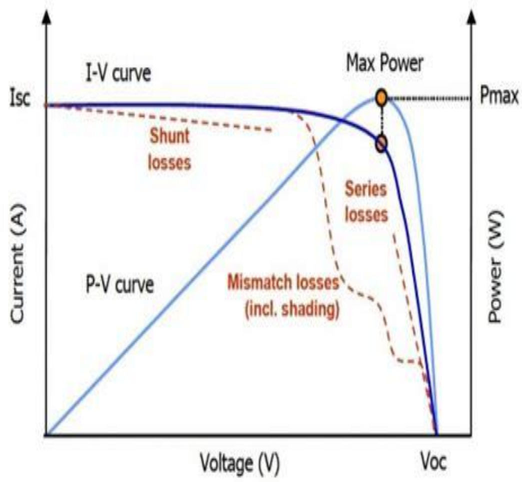

Figure 4: IV and PV Characteristics of Solar panel (Courtesy Google).

The 3-step charging process of lead acid batteries is depicted in Figure 5.

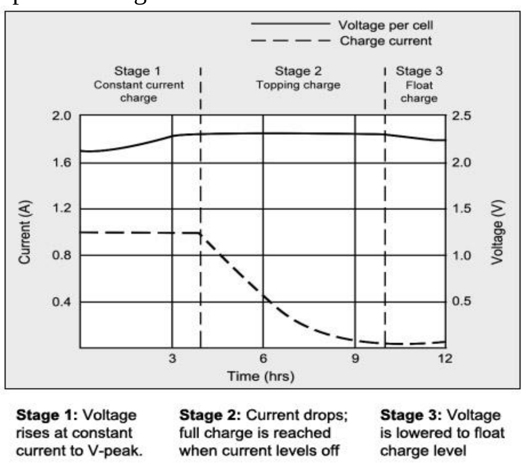

Figure 5: 3-Step Charging Process of Battery (Courtesy Battery University).

A 3-step process combined with P & O MPPT algorithm is used to to increase the reliability and life span of the system. As indicated in figure 4, during constant current stage the battery is charged to its 70% value, where in the voltage rises to its peak value. During 2^{nd} stage i.e., Constant voltage stage, the battery is charged to its remaining level of 30%, where the current drops to its minimum value of about 3%-5% of its Ah rating. The last stage is the float stage, during this stage the charging voltage is reduced to float level to avoid the self-discharging of lead acid batteries.

The overcharge control is implemented by detecting the fully charge condition of the battery and enabling float stage when charging current falls below 5% of its rated Ah. The deep discharge control is activated when battery charge level reaches its 10% level and load will be disconnected.

Further, to increase the useful life of system, IR based remote control is used to operate the electrical appliances connected. The IR control aids the operation and use of system by senior citizens, differently abled persons. Thus, the unnecessary power consumption is avoided, life of the battery and system is increased. A display system is incorporated to know the health of the system, which will help the user to maintain the system without difficulty.

The simulation and experimental models of the proposed system are presented in this section. Section 4.1 presents the simulation model, section 4.2 details the hardware model. Section 4.3 presents the results.

4.1 The simulation model of 30Wp Solar panel

The simulation model of 30Wp Solar panel is developed using Simulink/MATLAB.The Simulink model is shown in figure 6.

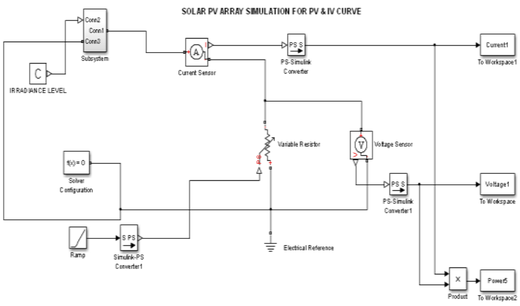

Figure 6: Simulation model of 30W Panel (36 cells)

The typical 30Wp solar panel characteristics extracted from data sheet are shown in figure 7.

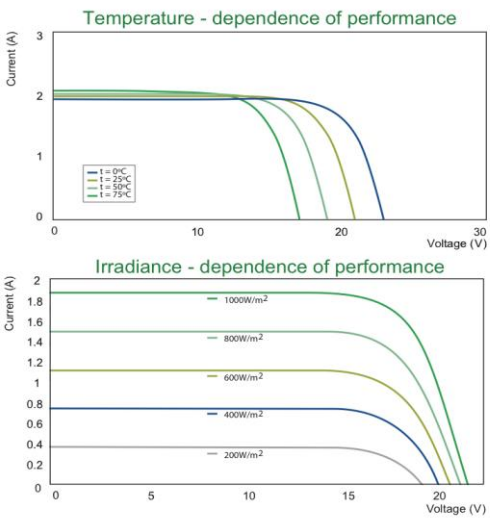

Figure 7: IV Characteristics of 30Wp Panel (Datasheet)

4.2 Experimental Prototype

The experimental model of the proposed system is shown in figure 8 and the remote in figure 9.

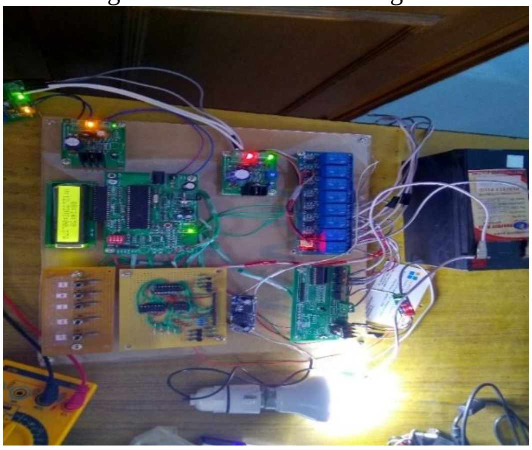

Figure 8: Experimental prototype of SHLS

Figure 9: IR Remote used in testing SHLS

The specifications of the home lighting system presented are in Table 1:

Table 1: Specifications of SHLS

GENERAL	
Application	Solar Powered Home Lighting System
Use	Indoor
Operating Temperature	0 to 50°C
System Components	
Module Type	36 cell Poly Crystalline
Open Circuit Voltage	21.6V
Module Power	30Wp
Battery	
Type	Sealed Lead Acid
Battery Voltage	12V Nominal
Battery Capacity	7.2 Ah
Luminary	
Lamp Type	LED 48 2 Ft DC/Bulb
Number of luminaries	2 nos +1 USB port
Lamp Wattage	5W
Mobile Charging port	5W
Nominal Working Voltage	12V DC

Power Consumption	15W±10% (All Luminaries)
Charge Controller	
Charging Process	Three step Process Charge controller
Charging Current	1.2A Max
Load Current	7A
Indications	Charging, Charge Full, Battery Low
Protection	Overcharge, Deep discharge, Reverse polarity,
Connecting Wires	
Module to Charge Controller	5mtrs
Battery to Charge Controller	0.5mtrs
Luminary to Charge Controller	5mtrs

To implement P & O algorithm, solar voltage and current are necessary. A signal conditioning circuit is necessary to acquire voltage and current values at the input and at the load side. This is important because the microcontroller accepts the signals of level between 0-5V only. The signal conditioning circuit is developed using an analog device LM358. The maximum voltage, current to be measured at the input side are 21V, 1.5A respectively. The built-in analog to digital converter (ADC) with 10-bit resolution is used to convert analog signal to digital. Similarly, the maximum voltage, current to be measured at the load side are 12V and 1.5A.

The signal conditioning circuit used to sense the voltage from solar panel and battery is shown in Figure 10.

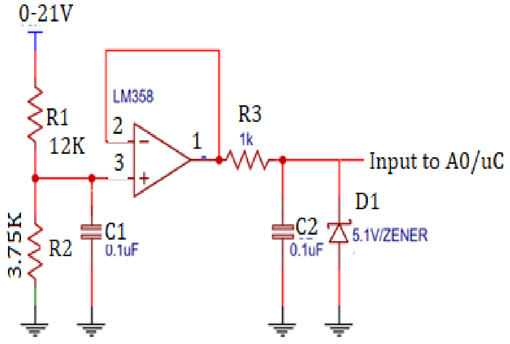

Figure 10: Signal conditioning circuit

The ½ LM358 is configured as voltage follower along with a voltage divider network to acquire voltage. The voltage at the output of LM358 is given by:

$$V_{A0} = V_i * \frac{3.75k}{12k+3.75k} \quad (2)$$

V_i= Input at the voltage divider

Where V_{A0}= Output of signal conditioning circuit.

$$V_{A0} = V_i * 0.238 \quad (3)$$

$$V_i = \frac{V_{A0}}{0.238} \quad (4)$$

The relation between the input and output of ADC is given by:

$$\frac{V_{A0}}{ADCcount} = \frac{V_{ref}}{2^N - 1} \quad (5)$$

Where V_{ref}= Full scale range of the ADC
N= Resolution of ADC.

$$V_{A0} = ADCcount * \frac{5}{1023} \quad (6)$$

$$V_{A0} = ADCcount * 0.00488 \quad (7)$$

Equating equations (3) & (7)

$$V_i = ADCcount * \frac{0.00488}{0.238} \quad (8)$$

$$V_i = ADCcount * 0.0205 \quad (9).$$

The combination of resistor R3 and Capacitor C2 forms a low pass filter to smoothen the signal.

Further, to acquire current at the input and output sides, a current sensor ACS712-05A Hall effect sensor is used. The circuit used to acquire current is shown in figure 11.

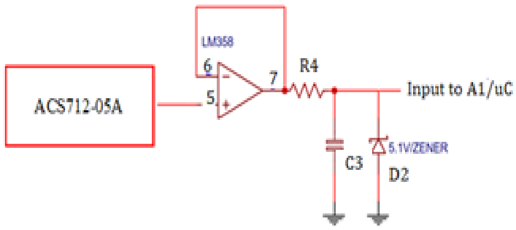

Figure.11 Current sensing circuit

The resistor R4 and C3 forms the low pass filter for the signal.
The sensitivity of the current sensor is 185mV/A and has offset voltage of 2.5V.

Therefore, the output of the sensor is given by:

$$V_{A1} = \frac{V_{cc}}{2} + 0.185 * I \quad (10)$$

$$V_{A1} = \frac{5}{2} + 0.185 * I \quad (11)$$

According to equation (5),

$$V_{A1} = \text{ADCcount} * \frac{5}{1024} \quad (12)$$

Equating equations (11) & (12) and simplifying

$$I = (\text{ADCcount} - 512) * 0.0264\ A (13).$$

V. SIMULATION AND EXPERIMENTAL RESULTS

The simulation and experimental results are presented in this section. The developed hardware prototype was tested as per the specifications listed in Table 1. The 30Wp solar panel of 36 cells was modeled using Simulink/MATLAB tool as given in section 4.

5.1. Simulation Results

The simulated IV/PV characteristics of 30Wp polycrystalline solar panels are shown in figure 12 and figure 13.

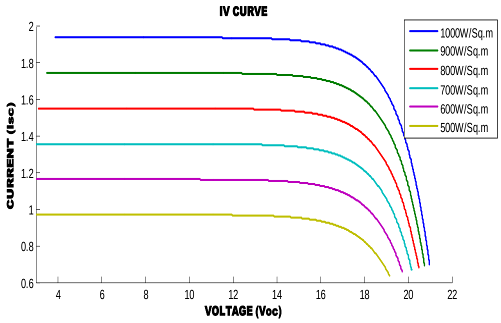

Figure 12: IV characteristics of 30Wp panel

Figure 12, shows the I-V characteristics of 30Wp solar panel, obtained at different irradiance levels.

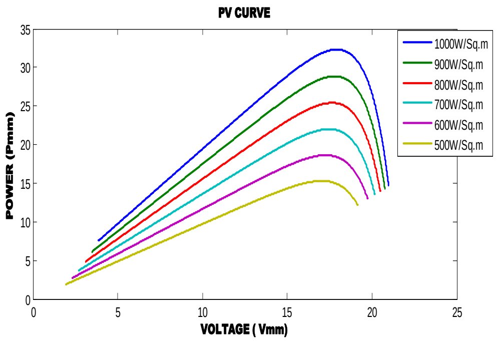

Figure.13 P-V characteristics of 30W Solar panel

Figure 13, shows the P-V characteristics of 30Wp solar panel, obtained at different irradiance levels.

The performance characteristics of 30Wp/36cells solar panel obtained by simulation are comparable with those of its typical characteristics presented in data sheet.

5.2 Experimental results

The experimental model shown in figure 8 was tested for its performance. Experiments on prototype were conducted in stages and details are:

i. Performance characteristics of 30Wp/36cells solar panel,
ii. Charging process with 3-step process along with MPPT,
iii. System operation with no remote and different loads.
iv. System operation with remote and different loads.

The performance characteristics of 30Wp polycrystalline solar panels obtained experimentally are shown in figure 14 and figure 15.

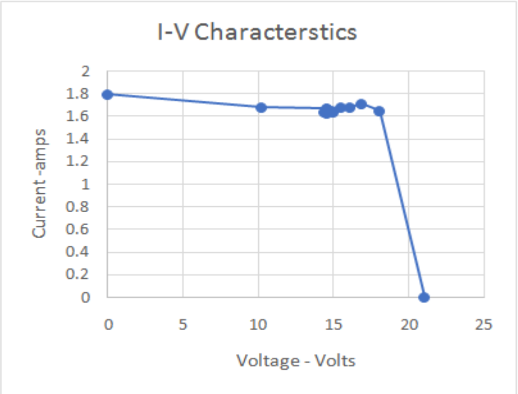

Figure 14:I-V characteristics of 30Wp Solar panel

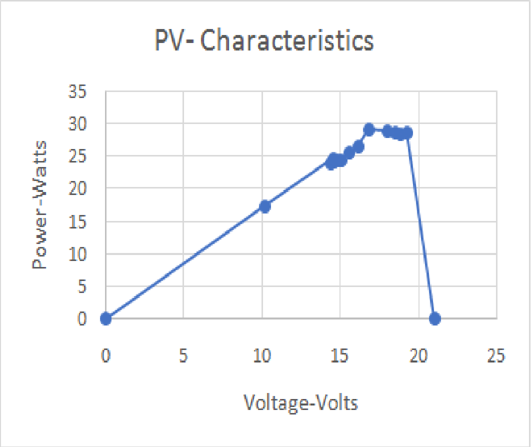

Figure 15: P-V characteristics of 30Wp Solar panel

The performance characteristics of 30Wp solar panel obtained experimentally and by simulation are in line with those of data sheet of the panel.

The battery charging time with different discharging levels of are tabulated in Table 2.

Table 2: Charging time of battery with 3-step process along with MPPT

Sl No	Condition	Charging Time
1	10% to 100%	10 hrs (Initially)
2	20% to 100%	8 hrs
3	50% to 100%	5 hrs

The utilization hours of the Solar Home Lighting System with different loads are tabulated in Table 3.

Table 3: Utilization hours of SHLS

Sl No	Load	Autonomy	Remarks
1	5W	14.5 hrs	
2	10W	7hrs	
3	15W	4.5hrs	

In addition to the lighting load, mobile charging port is provided in the system. The hours of autonomy changes when mobile charging is used.

VI. CONCLUSION

The design and development of Solar Home Lighting System with remote control was carried out. The simulation and experimental results of solar panel are comparable with those of data sheet. The performance of the developed prototype was satisfactory when subjected to test. The number of hours of autonomy is very high and definitely suitable for both rural & urban areas. The number of autonomy hours of the system is very good compare to the similar systems available in the market. The number of hours required to re-charge the battery is quite commendable. The system is more useful for senior and differently abled citizen due to its ease of operation through remote.

ACKNOWLEDGMENT

Authors would like to acknowledge the comments of senior citizen to whom the system was demonstrated to have their views on the developed SHLS with remote control. Their comments have enriched the authors knowledge and plan to implement the suggestions of senior citizen in future projects. The remote-controlled complete home lighting system was highly appreciated by the senior citizen.

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