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Maximum Power Point Tracking Control for Photovoltaic System : Particle Swarm Optimization Approach

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***Abstract*—Due to scarcity of fossil fuel and increasing demand of power supply, we are forced to utilize the renewable energy resources. Making full use of abundant renewable solar energy through the development of photovoltaic (PV) technology is an effective means to solve the problems such as difficulty in electricity supply and energy shortages in remote rural areas. The mathematical modeling and simulation of the photovoltaic system is implemented in the MATLAB/Simulink environment and the same thing is tested and validated using Particle Swarm Optimization. This paper presents Maximum Power Point Tracking Control for Photovoltaic System Using "PSO". The PV array has an optimum operating point to generate maximum power at some particular point called maximum power point (MPP). To track this maximum power point and to draw maximum power from PV arrays, MPPT controller is required in a stand-alone PV system. Due to the nonlinearity in the output characteristics of PV array, it is very much essential to track the MPPT of the PV array for varying maximum power point due to the insolation variation. The MPPT method based on PSO algorithm is established and simulated with Matlab/Simulink. The output of the controller, pulse generated from PWM can switch MOSFET to change the duty cycle of boost DC-DC converter. The result reveals that the maximum power point is tracked satisfactorily for varying insolation condition. The design, construction, and the beginning testing of an experimental hardware prototype is presented, with the test results included.**

Keywords—Photovoltaic; Pulse Width Modulation; Proportional Integral Controller; boost DC-DC; PSO; PV emulator.

I. INTRODUCTION

Today photovoltaic (PV) systems are becoming more and more popular with increase of energy demand and there is also a great environmental pollution around the world due to fossils and oxides. Solar energy, which is free and abundant in most parts of world, has proven to be economical source of energy in many applications [1]. The energy that the earth receives from the sun is so enormous and so lasting that the total energy consumed annually by the entire world is supplied in as short a time as half an hour. The sun is a clean and renewable energy source, which produces neither greenhouse effect gas nor toxic waste through its utilization. It can withstand severe weather conditions, including cloudy weather. The watt peak price is decreased since the seventies, this leads to large-scale promising areas. It does not have any moving parts and no materials consumed or emitted. Unfortunately, [4] this system has two major disadvantages, which the low conversion efficiency of electric power generation (9 to 16%), especially under low irradiation conditions and the amount of electric power generated by solar array changes continuously with the weather conditions like irradiation and temperature. To overcome this problem, maximum power point tracking (MPPT) technique will be used.

Particle Swarm Optimization control. The tracking algorithm integrated with a solar PV system has been simulated with boost DC-DC converter in stand - alone PV system. The proposed PV system with boost DC-DC converter is shown in Fig.1. The given model operates very fast in proper accuracy in maximum power point tracking (MPPT).

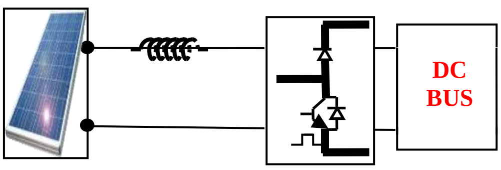


Fig.1. Photovoltaic module with DC-DC boost converter.

II. MATHEMATICAL MODELING OF PHOTOVOLTAIC CELL

The mathematical model associated with a cell is deduced from that of a diode PN junction. It consists on the addition the photovoltaic current I_{ph} (which is proportional to the illumination), and a term modeling the internal phenomena [7]. The electrical equivalent circuit is shown in Fig.2.The cell output current I, is then written:

$$I = I_{ph} - I_0 * (e^{q*(V+R_s*I/n*k*T)} - 1) - (V + R_s * I / R_p)$$

I = photovoltaic current.

I_O = saturation current.

$V_t = N_S k T/q$, thermal voltage of array.

Ns = cell connected in series.

T = is the temperature of the p-n junction.

k = Boltzmann constant.

q = electron charge.

R_S = equivalent series resistance of the array.

R_P = equivalent parallel resistance of the array.

a = diode ideality constant.

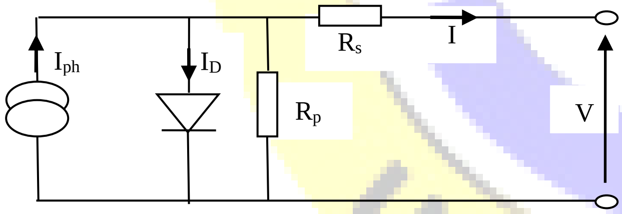


Fig. 2 Equivalent circuit of PV cell

The SCA module BP Solar 3160 is selected like model of simulation under MATLAB/Simulink. It belongs to the series of module SX™ of BP Solar. Tab.1 summarizes its standard electric characteristics:

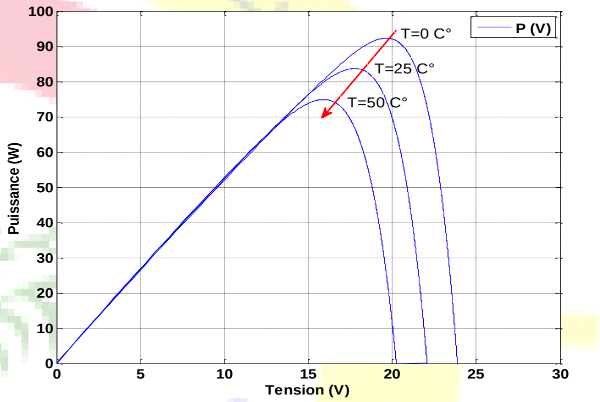
TABLE 1. PV Panel Parameters

Parameter	Value
Maximum Power	50 W
Operating Voltage	16.8 V
Operating Current	2.97 A
Short-circuit Current	3.23 A
Open circuit Voltage	21 V
Temperature coefficient of Isc	(0.065±0.015)%/°C
Temperature coefficient of Voc	(80±10) mV/°C
Temperature coefficient of the Power	(0. 5±0.05) %/°C

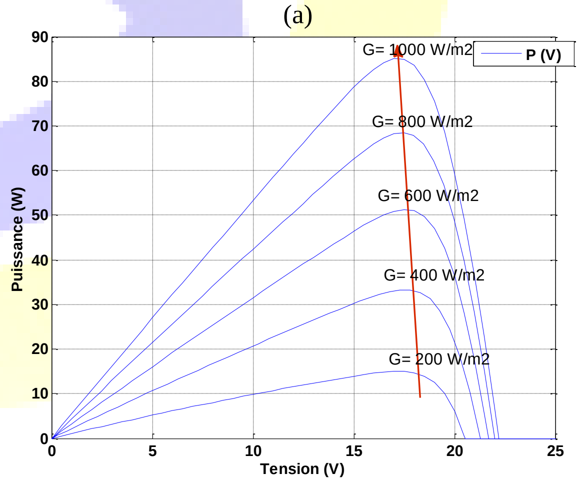
Fig. 3(a) and Fig. 3(b) give the power voltage (P-V) characteristics of a PV module for different values of solar radiation and temperature. The short circuit current is clearly inverse dependence to the temperature; an increase in temperature causes a reduction of the open-circuit voltage (when sufficiently high) and also more maximum output power.

Simulated I-V, P-V characteristics for the maximum power point tracking (MPPT) is shown in Fig.4.

At this Maximum Power Point (MPP), the solar array is matched to its load and when operated at this point the array will yield the maximum power output. From Fig. 4 (a) & (b), it is observed that the power output has an almost linear relationship with array voltage unit, hence the MPP is attained. Any further increase in voltage results in power reduction. [5]



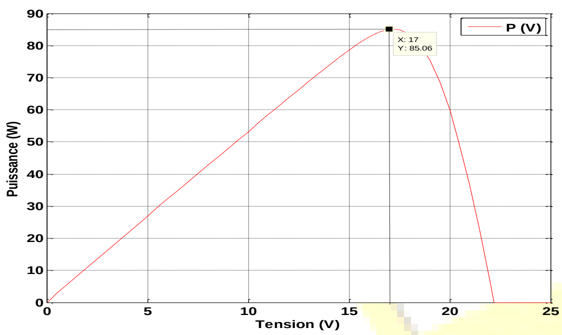
(a)



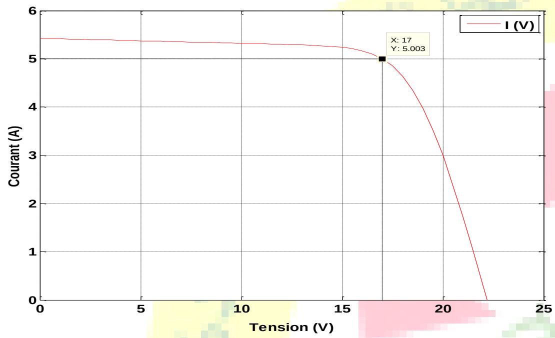
(b)

Fig.3. Simulated waveforms showing the effect of

(a) Temperature and (b) Irradiation on P-V characteristics.



(a)



(b)

Fig.4. PV array simulated curves

I-V curve (25°C) and (b) P-V curve (1000w/m2).

III. DC – DC BOOST CONVERTER

A dual stage power electronic system comprising a boost type dc-dc converter and an inverter is used to feed the power generated by the PV array to the load. To maintain the load voltage constant a DC-DC step up converter is introduced between the PV array and the inverter. The block schematic of the proposed scheme is shown in Fig.5.

In this scheme, a PV array feeds DC-DC converter used in step-up configuration. For a dc-dc boost converter, by using the averaging concept, the input–output voltage relationship for continuous conduction mode is given by:

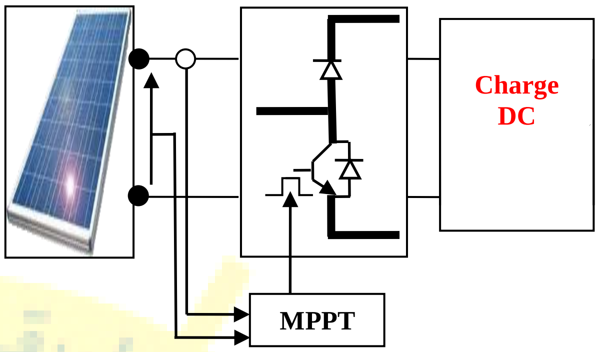


Fig. 5 A MPPT Controllers in a PV System

$$\frac{V_o}{V_{in}} = \frac{1}{(1-D)} \tag{2}$$

Where, D = duty cycle. Since the duty ratio "D" is between 0 and 1 the output voltage must be higher than the input voltage in magnitude. [2-3]

IV. PSO MPPT CONTROLLER

A. The Principle of the Particle Swarm Optimization Algorithm :

Particle swarm optimization (PSO) is an evolution computing technology based on swarm intelligence, which was proposed by Eberhart and Kennedy in 1995, and it is based on the simulation of the flock. The principle is described as follows: a flock of birds search food randomly in a region where there is only a piece of food. The most simple and effective strategy to find food is to search the area around the nearest bird from food, which constitutes one of the basic concepts of the PSO. Assuming that a community is composed of n particles in a D-dimensional search space, wherein Xi is the position of i-th particle in D-dimension [6, 8].

$$X_i = (X_{i1}, X_{i2}, \ldots\ldots, X_{id}),\ i = 1,2,\ldots, n \tag{3}$$

Fitness value can be calculated by substituting Xi into an objective function, and the pros and cons of Xi can be obtained according to the size of the fitness value. "Flying" velocity of the particle i is a D-dimensional vector, denoted as

$$V_i = (V_{i1}, V_{i2}, \ldots\ldots, V_{id}),\ i = 1,2,\ldots, n \tag{4}$$

And

$$P_i = (P_{i1}, P_{i2}, \ldots\ldots P_{id}) \quad i = 1,2,\ldots\ldots n \tag{5}$$

Is the best position of particle i searched, corresponding to the optimal solution particle i found by itself, which is the location of the best fitness value. Optimal position for the entire particle swarm search after the h-th iteration is

$$P_{igd} = (P_{i1}, P_{i2}, \ldots\ldots P_{id}) \tag{6}$$

By the above definition, the standard formula of PSO can be expressed as:

$$V_i^{k+1} = w * V_i^k + c_1 * r_1 * (P_{id}^k - X_{id}^k) + c_2 * r_2 * (P_{gd}^k - X_{id}^k) \tag{7}$$

$$X_{id}^{k+1} = X_{id}^k + V_{id}^k \tag{8}$$

where i is the number of particles in the swarm; d represents the dth-dimension of particles; ω is the inertia weight coefficient; r_1, r_2 are the random values between [0, 1]; c_1 called cognitive factor represents belief degree on experience, which can be used to adjust the step size of particles to fly towards the direction of its local best position; c_2 known as the coefficient of social learning represents the belief degree on individuals around, which can be used to adjust the step size of particles to fly towards the direction of its global best position. The algorithm iteration termination condition is generally chosen as the maximum number of iterations or fitness value, which satisfies the predetermined threshold value of the minimum fitness after searching the optimal location.

PSO algorithm is easy to operate and simple for use with a fast convergence. However, the algorithm also has the following problems:

1) The particles are "flying" toward the direction of the optimal solution. However, if the inertia factor is large, it is difficult to obtain the optimal solution, and the search accuracy will reduce.

2) All the particles are "flying" toward the direction of the optimal solution, but the closer the optimal particle comes, the less its searching speed becomes. Particle swarm deprives the diversity of solutions between the particles, and thus the algorithm may converge to a local maximum without difficulty, which is not always the same as the global maximum and fails to track the actual global maximum.

B. MPPT has been Design using Particle Swarm Optimization Algorithm:

In this paper, one photovoltaic panels connected are used for example to analyze the process of algorithm design. The program flowchart of the IPSO algorithm introduced in this paper is shown in Figure 6.

The specific procedure is as follows:

- Initialization of the population parameter:

  Population number and the number of these individuals in the group are initialized; evolution algebra is set; the parameters of the learning factor, the weighting coefficients and maximum speed are initialized; each particle's initial position and velocity of each particle are given in a random way.

- Calculation of the fitness value of each particle:

  After various parameters have been initialized, the adaptation value of the objective function for each particle is calculated. The objective function is the power output of the array, and the fitness function expression is:

  $$Power = V * I \tag{9}$$

  Where I is the output current of the PV array, V represents the output voltage of the photovoltaic cell module.

- Find individual optimal location:

  Every individual in evolution has an optimal position in the individual history, namely individual extremum. This individual fitness is compared with the fitness value of the particles (the maximum power of the system). If current value is better, then the position with current position as well as the fitness value is updated simultaneously.

- Find the global optimal position:

  Each individual has a history optimal location. For the whole group, there is also a global optimal position. The best particle of group with the best fitness value is determined. The optimal position is the position of the optimal individual in the population.

- Update the particle velocity and position:

The speed of particle swarm model is equivalent to actual model of the current increment. Position is equivalent to the current of the actual model. The position and velocity of each particle are updated according to formula (3) and (7).

- Determine the termination condition:

End conditions are maximum evolution generation. The search is terminated when the iteration becomes the maximum evolution generation. Otherwise, the evolution algebra pluses 1 automatically, and returns to step 2. The optimal solution Imax is the current value at the maximum power point.

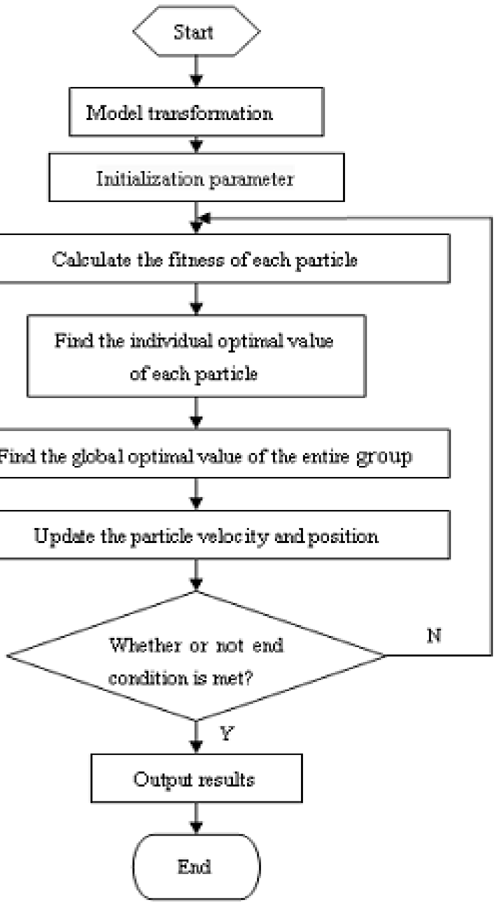


Fig. 6 Flowchart of the PSO algorithm

V. RESULTS AND DISCUSSION

Simulation of PSO algorithm as MPPT on PV system is done by providing interference in the form of solar irradiation and temperature changes because these two variables affect PV output voltage and current.

In this condition the output voltage transient response of boost converter shows the simulation results by giving solar irradiation disturbance. At the initial conditions for solar irradiation of 1000 W/m2 and changes until 800W/m2 in t=0.5s and in t=1s increased to its initial conditions.

At the initial conditions, the PV temperature of 50ºC then decreased at a temperature 25ºC with different value of solar irradiation. From t=0.5s to t=1s the fixed temperature 50ºC and solar irradiation decreased from 1000 W/m2 to 800 W/m2, PV output power of 43W and will decreases to low value which causes by the decrease of the current in the output of the boost.

This suggests that changes in solar irradiation will lead to changes in the PV output current. The MPPT controller produce change, as shown in Fig 11.

From t=1s to t=1.5s the fixed solar irradiation 800 W/m2 and temperature decreased from 50ºC to 25ºC, PV output power of 36 W and will increases to high value which causes by the decrease of the current in the output of the boost as shown in Fig 9,caused by the changing of the value of the duty as shown in Fig 10 . This suggests that a change in PV temperature is inversely proportional to changes in the PV output current.

From t=2s to t=2.5s the fixed temperature 25ºC and solar irradiation increased from 800 W/m2 to 1000 W/m2, PV output power of 37 W and will increases to high value as shown in Fig 9,which causes by the increase of the current in the output of the boost as shown in Fig 10.

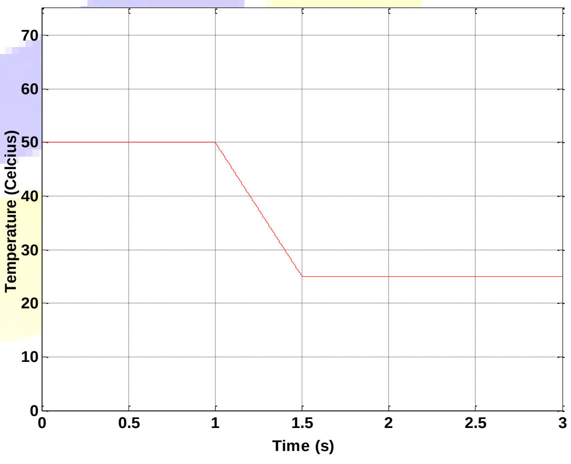


Fig.7 Solar temperature change

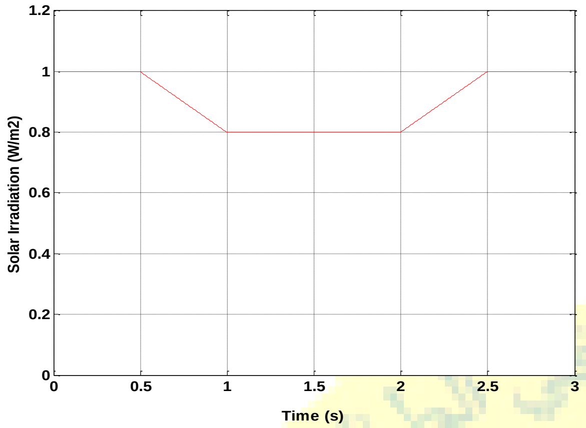


Fig.8 irradiation temperature change

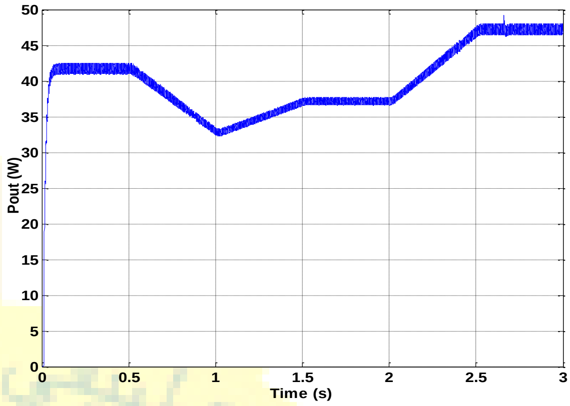


Fig.11 Power (W) output of the boost

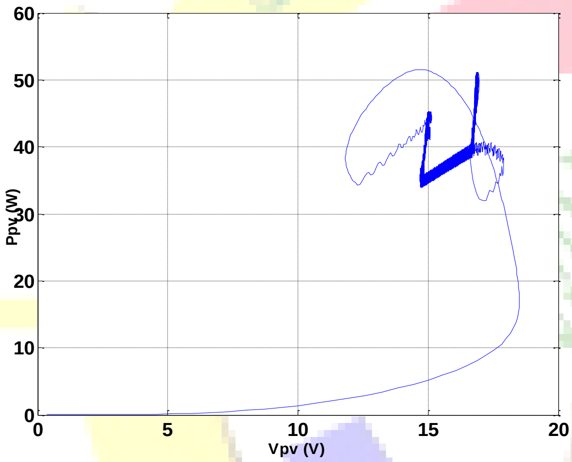


Fig.9 MPPT characteristic P-V

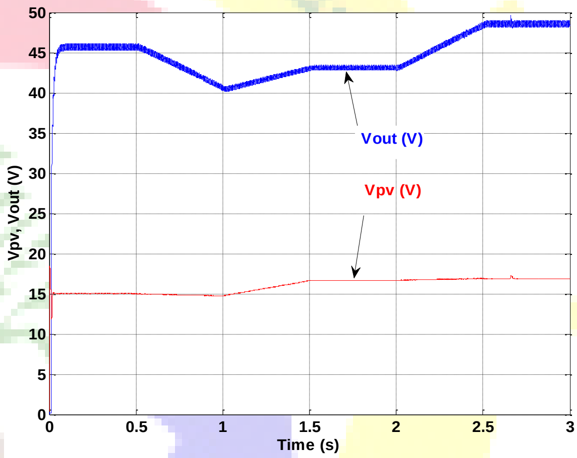


Fig.12 Voltage (V) the PV and output of the boost

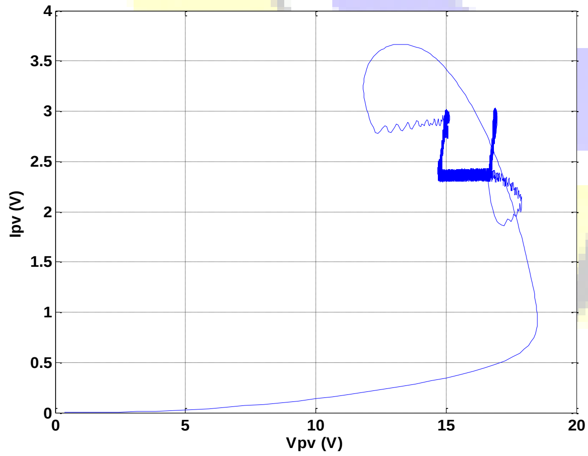


Fig.10 MPPT characteristic I-V

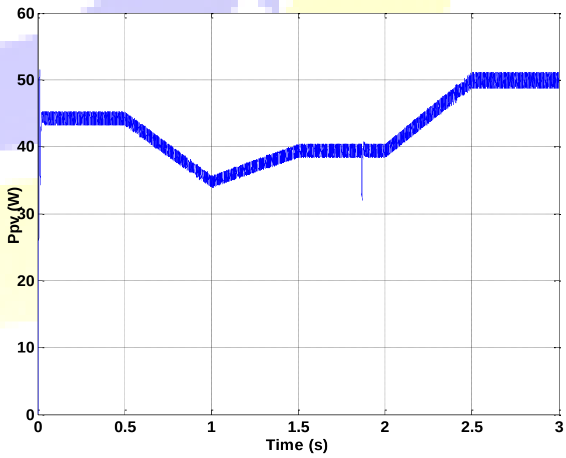


Fig.13 Power (W) for PV model

VI. CONCLUSION

This paper has presented particle swarm optimization for controlling PV system output voltage to operate at maximum power point although happened temperature and irradiation changes.

Applications of PSO controller on MPPT of PV showed a good performance. The system was analyzed and designed, and performance was studied by simulation with Simulink/Matlab. PV system can operate at maximum power point although occur temperature and sun irradiation change that can shift maximum power point.

VII. REFERENCES

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