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SIMULATION STUDY OF PARTIAL POWER PROCESSING WITH BOOST CONVERTER FOR SOLAR PV APPLICATION

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Abstract: DC/DC converters which form an interface between the PV panel and the batteries/inverters are integral part of any PV power plant. The Major function of converter is to transfer maximum possible power from the solar PV panel to the load. PV system with DC/DC converter which uses partial power processing technique is implemented in this paper. This topology is deemed to be advantageous in many aspects such as simplicity, high efficiency, low cost and higher reliability. To enhance the efficiency of the converter output must be obtained with the help of input PV power fed forward to the output without processing, further more only a small portion of the input power is framed by the converter depending upon the voltage regulation requirements. Here perturb and observe MPPT algorithm is adopted for location maximum power points at any sunlight condition for withdrawing the maximum possible power from the PV panel and relegating that power to the load. The performance of this topology is analyzed with the MATLAB Simulink model.

Keywords: DC-DC Converters; Partial power processing (PPP); Maximum power point tracking (MPPT); Photovoltaic (PV); Perturb and Observe (P&O) algorithm.

1. INTRODUCTION

With ever increasing requirement of electrical energy the necessity of a secured and abundant source became quite prominent. Due to energy scarcity, the demand of renewable energy sources had become extremely high. Keeping these very factual technicalities in mind, few highly promising renewable energy sources had been taken into account one of them is solar PV. Despite of so many advantages of photovoltaic systems, they do not exhibits desirable efficiency. For the prescribed system, efficiency is a function of several factors namely temperature, irradiation, dust and shading, resulting in inadequate performance. In order to extricate this deficiency, maximum power should be relegated from the PV panel. For that MPPT scheme is used to improve the overall performance of PV system [1]. Numerous MPPT schemes are available and each single one of them has its own existence so it is very important to have a detailed study and understanding of these widely accepted techniques. Here in this work we are using P&O MPPT algorithm. To implement any MPPT scheme, it is required to have a dc/dc converter into the system which acts as a medium between the load and the panel. Irrespective of any condition such as environmental and the load behaviour, the control system of the converter makes sure that operating point is optimized for maximum possible power transfer [2]. It is very important to design the PV system with proper dc/dc converter for minimizing the losses involved in the process [3, 4]. Usage of PPP topology of dc/dc converter has been made in the presented work. The bulk emphasis is laid to achieve higher efficiency, proper reliability, lower cost, and obtaining high output. The input of converter has a specific choice, can either be one from multi crystalline silicon (mc-Si) string or multiple cadmium telluride (CdTe) strings. The converter consists of two inter-weaved channels in order to have reduced input current ripple. Maximum expertise is maintained with the help of PPP scheme and also by the function of either of the two inter-weaved channels at lighter loads. In addition to this, in very lower range of loads, the converter is made to function in discontinuous conduction mode to minimize transient losses.

2. THE PHOTOVOLTAIC TECHNOLOGIES

The principle of PV system is described as direct conversion of light into electricity. A PV cell provides very low voltage output of around 0.5V, thus a number of PV cells are combined in series and parallel in order to obtain high voltage and power output to form a PV system according to application. Figure 1 depicts the block diagram of a PV system. The converters along with the MPPT schemes have to be tailored for each of the purpose. Thus it reduces the standardization possibilities to a great extent also lowers the expenditure of substantial production.

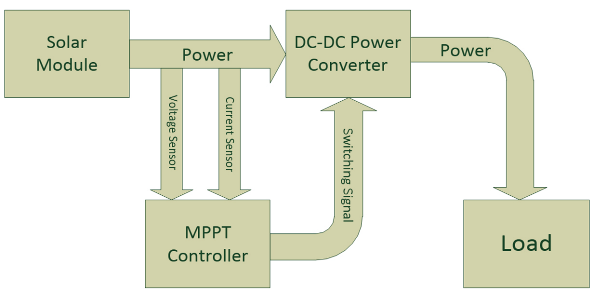


Figure 1: Block Diagram of Conventional Photovoltaic System

Numerous models have been presented for depiction of PV panel but two-diode representation is deemed to be highly precise. Figure 2 depicts the equivalent circuit of PV panel with two diode model [5, 6] and in addition to that the I-V characteristics of two-diode model given by (1) also the characteristics I-V and P-V curve are demonstrated in Figure 3.

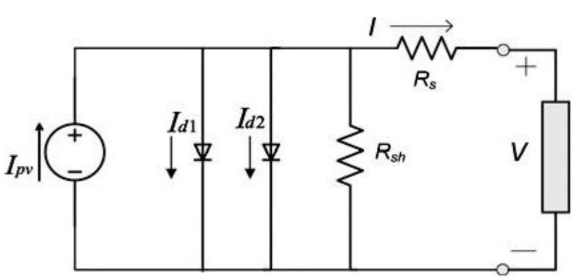


Figure 2: Equivalent Circuit of PV Panel with Bi-Diode Model

The output current of the panel is given by:

$$I = I_{PV} - I_{d1} - I_{d2} - \left(\frac{V + IR_s}{R_{sh}}\right) \quad (1)$$

$$I_{d1} = I_{01}\left[\exp\left(\frac{V + IR_s}{N_S KTA_1}\right) - 1\right] \quad (2)$$

$$I_{d2} = I_{02}\left[\exp\left(\frac{q(V + IR_s)}{N_S KTA_2}\right) - 1\right] \quad (3)$$

where,

- q Charge of Electron (1.6×10^{-19} C);
- K Boltzmann constant (1.38×10^{-23} Nm/K); T Temperature of PV Panel in Kelvin;
- I_{01} Reverse saturation current of diode 1;
- I_{02} Reverse saturation current of diode 2;
- A_1 Ideality factor of diode 1;
- A_2 Ideality factor of diode 2;
- I_{PV} Current due to incident light in PV panel in Amperes;
- R_S Series resistance of PV Panel;
- R_{sh} Shunt resistance of PV Panel;
- N_s Number of series connected PV cells;
- I Output current of PV panel in Amperes;

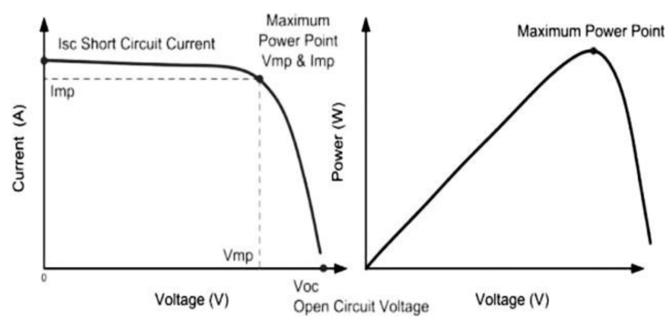


Figure 3: Characteristics I-V and P-V Curve of PV Panel

The proficiency of photovoltaic system is a function of many factors those are temperature, irradiation, dust and shading, due to which inadequate performance may be noticed. In order to extricate this deficiency, maximum power should be relegated from the PV panel. For that MPPT is utilized to optimize the proficiency of overall PV system [7]. Two types of MPPT techniques named Indirect and direct techniques are described in literatures [10]. The Indirect technique uses a set of database to track MPP having curves at various irradiation and temperature with the help of equations obtained from a unique set of data and parameters. Whereas, In Direct control schemes tracking of MPP are not based on any database or previously collected parameters, instead it adopts the real time calculation of PV voltage/current to have MPP. Here in this work we are using a direct MPPT scheme named Perturb and observe MPPT algorithm [8]. In which PV voltage/current is initially perturbed and thereafter the obtained PV power is used to confirm the side of next alterations of the PV voltage/current. Now, when the power is enhanced by perturbation then either voltage/current is altering in that direction awaiting the power begins to fall. This technique perturbs the system periodically if the variation in functioning point is positive, else it changes the direction of perturbation when it's negative. The proficiency of P&O algorithm is around 96% and the increment in energy extrication is 16% to 43% which is the spectrum of power gain with P&O MPPT algorithm [9].

3. PPP DC-DC BOOST CONVERTER

In a Partial Power Processing topology of converters they only process a percent of the input power to transfer it to the battery/load shown in Figure 4(b), unlike a conventional scheme as we can see in Figure 4(a), where the entire power is processed inside the converter. The partial power processing scheme is also useful in reducing the converter power rating [11].

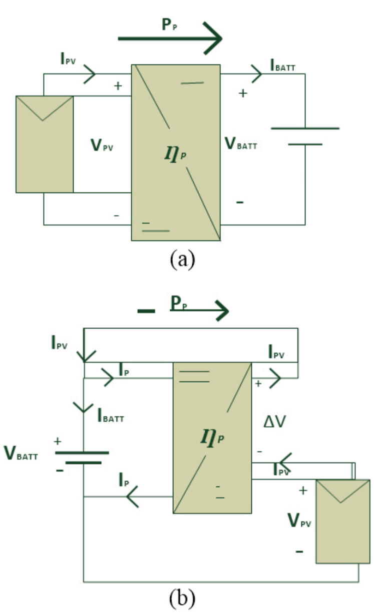


Figure 4: Block Diagrams (a) Conventional Scheme (b) PPP Scheme

According to the detailed and comparative study of PV system with different dc/dc converter scheme/topology in [12], scheme of power converters with string or multichannel, results in best rendition per cost trade off point [14-22]. As already stated that efficiency and reliability of PPP topology with multiple channels is higher than that of other topologies. The overall design complexity of PPP topology with multiple channel is less as compared to others so it also reduces the overall cost of the process. Hence with these qualities the PPP topology with multiple channel is much suitable for diiferent PV applications.

Table 1.
Comparison of Different Topologies

Topology → / *Parameter ↓*	*3-Level Boost*	*Partial Power Processing Converter*	*Partial Power Resonant Converter*	*Full Bridge*
Efficiency	High	High	High	Medium
Design Complexity	Low	Low	High	Medium
Reliability	Medium	High	Low	Medium
Power Density	High	Medium	High	Low
Cost	Low	Low	High	High

In a conventional scheme, the PV power P_P, is fed directly to the converter and processed at an efficiency of η_P. Thus for this system:

$$P_{BATT} = \eta_P \, P_P; \tag{4}$$

$$P_P = V_{PV} \, I_{PV}; \tag{5}$$

where, P_P is the processed power, and PBATT is the power transferred to the battery. The thermal losses are then found to be

$$P_{loss} = (1 - \eta_p)P_P = (1 - \eta_P)V_{PV} \, I_{PV} \tag{6}$$

In the PPP scheme, series connection is made to connect the converter and the battery/load, where only the difference in voltage between the buses ΔV is processed through the converter. As a result, the battery and PV connected to the ground, so then dc/dc converter becomes isolated and in this case expression P_P is:

$$P_p = \frac{\Delta V I_{PV}}{\eta_P} \tag{7}$$

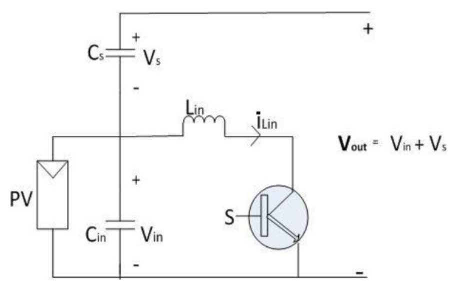
where, P_P is proportional to the difference in voltage instead of full battery voltage, ΔV is defined as:

$$\Delta V = V_{BATT} - V_{PV} \quad (8)$$

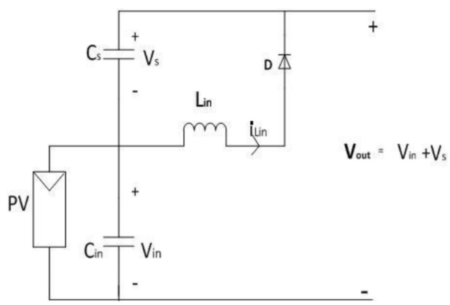
The loss expression then becomes:

$$P_{loss} = \frac{(1-\eta_P)P_P}{\eta_P} = \frac{(1-\eta_P)}{\eta_P}\Delta V I_{PV} \quad (9)$$

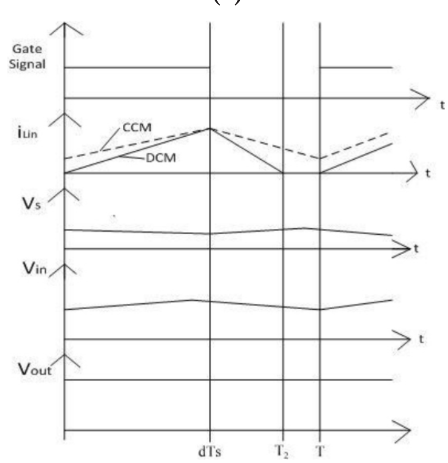
With sufficiently low ΔV, P_{loss} decreases and the efficiency increases. Figure 5(a) and (b) depicts the mode of operation for PPP converter scheme and related waveforms shown in Figure 5(c), which are entirely symmetric to that of boost converter.



(a)



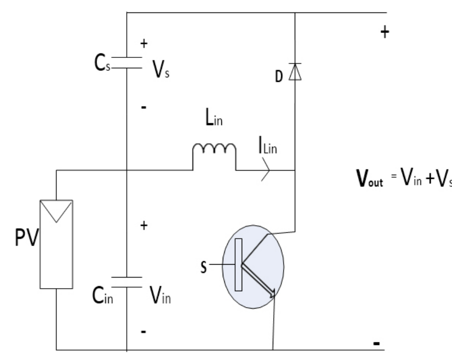
(b)



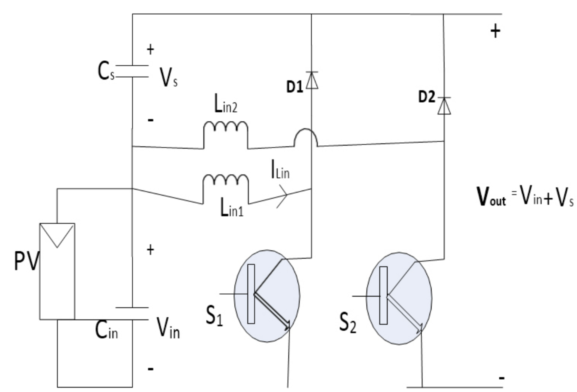
(c)

Figure 5: Modes of Operation of PPP Boost Converter (a) Mode 1 (0 < *t* < dTs) (b) Mode 2 (dTs < *t* < T) (c) Corresponding Timing Waveform

Figure 6 (a) depicts the circuit diagram of PPP with boost converter for PV system. This scheme becomes flawless with two inter-weaved channel design of the converter shown in Figure 6(b) with solitary switching device and a diode per channel. With this design, the converter shows rapid, distortion less and reliable process under load changing conditions [13].



(b)



(c)

Figure 6: PPP DC/DC Boost Converter (a) One Channel (b) Two Channel. [16]

The converter consists of two inter-weaved channels for reducing input current ripple [11]. Conventional converter scheme for photovoltaic system is made up of a high- frequency transformer but partial power processing boost converter scheme doesn't need to add a high frequency transformer, as a result the design becomes more simplified and lowers the cost.

4. SIMULATION AND RESULTS

To authenticate the genuineness of the PPP dc/dc boost converter alongside MPPT control the MATLAB/Simulink software was taken into account to accomplish the simulation process.

Table 2
Converter Parameters

Parameters	*Values*
Switching frequency	30 khz
R_L	14.5 Ω
C_{in}	460 μF
C_s	230 μF
L_{in1}, L_{in2}	2000 μH, 2000 μH

Figure 7 depicts the MATLAB/Simulink diagram of a conventional interfacing of Boost converter with PV module With P&O MPPT control scheme and Figure 8 depicts the MATLAB/Simulink diagram of PPP dc/dc Boost Converter without and with P&O MPPT control algorithms.

The output waveforms of the conventional scheme of dc/dc Boost converter with PV system is shown in Figure 8 followed by output waveforms of a PPP

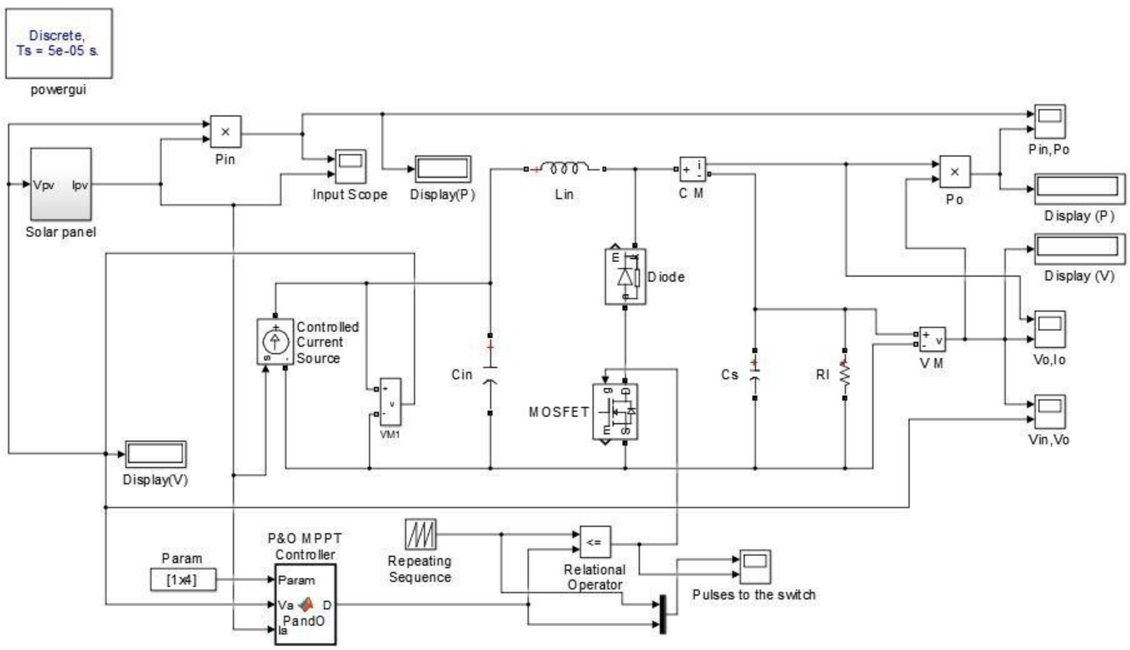


Figure 7: MATLAB/Simulink Diagram of PV System with DC/DC Boost Converter and MPPT Control

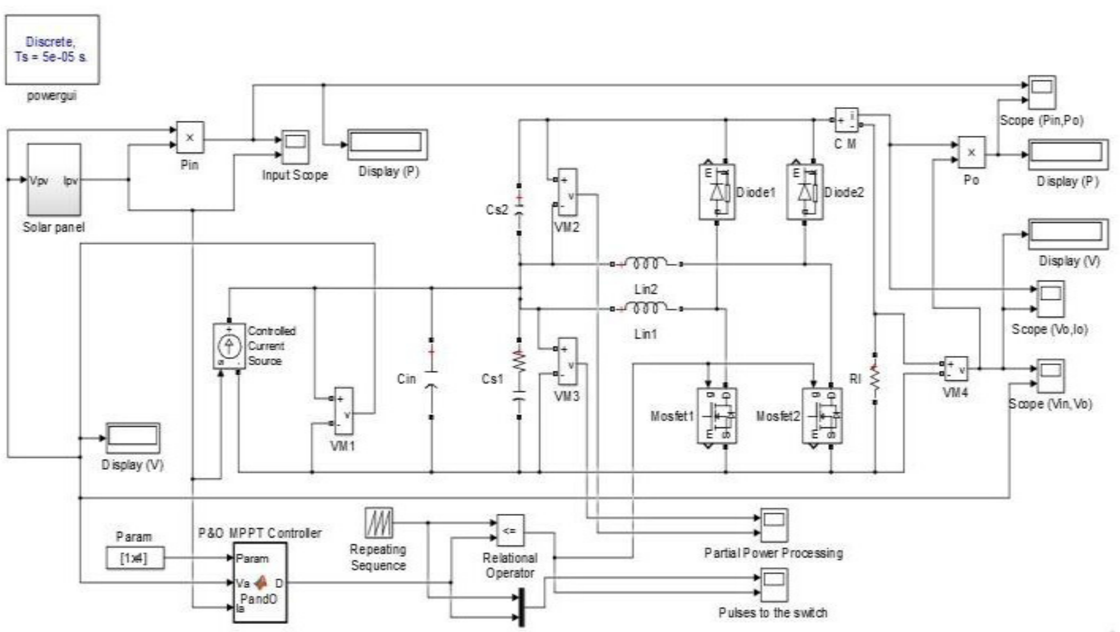
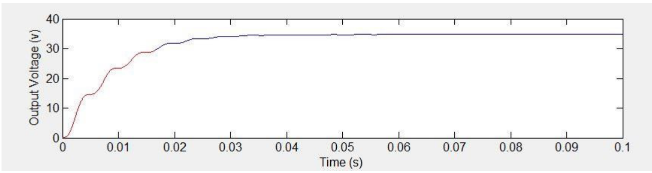
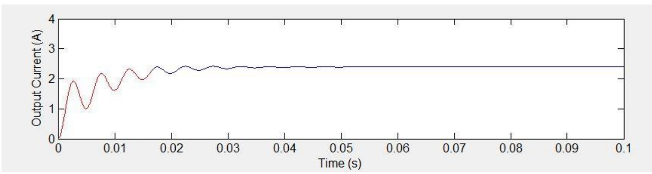


Figure 8: MATLAB Simulink Diagram of PPP DC/DC Boost Converter with Solar Photovoltaic System with MPPT

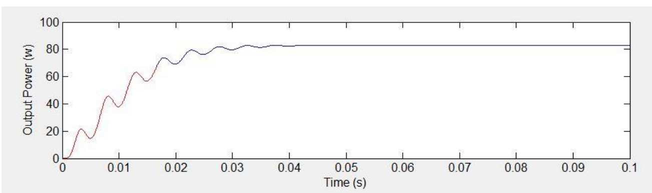
scheme dc/dc boost converter with MPPT control Photovoltaic system is shown below in Figure 9.



(a)

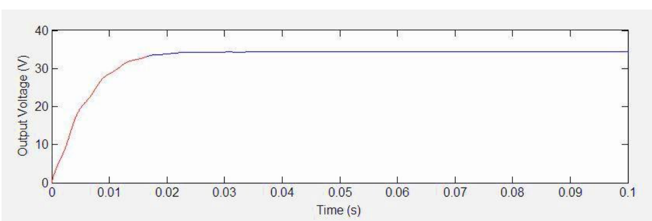


(b)

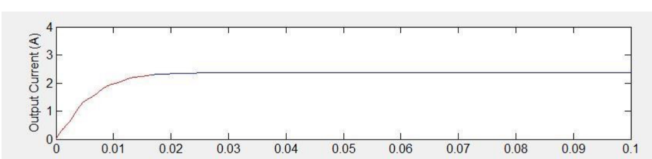


(c)

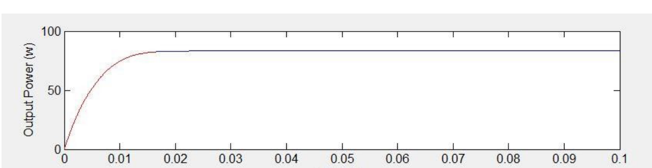
Figure 8: Output Waveforms of DC/DC Boost Converter (without PPP scheme): (a) Output Voltage (b) Output Current (c) Output Power



(a)



(b)



(c)

Figure 9: Output Waveforms of PPP DC/DC Boost Converter with MPPT Control: (a) Output Voltage (b) Output Current (c) Output Power

It is evident after observation of waveforms under conventional and PPP scheme of interfacing of boost converter with PV module that former consumes more time in reaching steady state as compared to that of PPP scheme. Moreover, it is also seen while reaching steady state, the fluctuations are almost negligible as compared to that in conventional scheme. Therefore, PPP topology with multiple channels is found to be more reliable and efficient than conventional scheme of using boost converter with PV module.

5. CONCLUSION

This hypothesis of partial power processing is used to recognize a high efficiency light weight converter which carries out MPPT control to transfer the power from solar panel to the battery/load. It is concluded that with interweaved channel of Boost converter in PPP scheme the input current ripple gets reduced, also the weight, size and design complexity of the converter diminishes. The conventional interfacing of boost converter and PPP topology of boost converter with PV module is simulated and their output is realized. Simulated results show better performance and fulfilment of the objectives of implemented design. This scheme of partial power processing in solar PV system is very beneficial in improvement and optimization of solar powered conveyance, electric unmanned aerial vehicles and manned solar aircraft. As the usage in these application is multidisciplinary where variable quantities such as weight of power converter and reliability of conversion process are an important role-player in the collective optimization process.

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