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Constant DC-DC Converterwith Variable Voltageand Load Resistivein Pico Hydro Turbine Generator System

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ABSTRACT

This paper presents a design which improves DC-DC converter that can be used in Pico hydro generation system and deals with low flow water to generate green energy power. The green energy power generates from the transformation of potential power in flow rate water to electrical voltage. The proposed DC-DC converter is used to convert the potential voltage in a variable low water flow to produce electric power, done by applying a Single Boost converter and Constant lock circuit CLC that can raise the input voltage to another fixed DC output voltage which is called hybrid operation mode. Then, the converter output voltage is measured and compared with fixed voltage using MATLAB/ Simulink and Proteus Software. The results of the proposed design showed the ability to produce a constant 24v with a variable both input voltage from (5–18) v and resistive load in a high-performance response.

Keywords: Pico turbine generator, combination DC-DC converter, Constant lock circuit.

1. INTRODUCTION

Recent Pico turbine generator can generate 5 kW as a maximum output power. It is a very useful power that generates by Pico turbine especially to a remote village that has approximately consumption power less than 5 kW, for example, led lights, TV, and radio [1, 2]. Pico turbine generator also helps for upgrading the existing levels of people especially in poor and a remote region which is very expensive for the governments to find the transmission line [3, 4]. These days, the innovation in improving this green technology is helpful and encouraging. These efforts provide several benefits regarding cost-effective, capacity and size of the design if it compares to other larger hydro turbine generators. Many countries depend on Pico-hydro generation system due to unstable of oil prices. Hence, Pico hydro generation system becomes people's best option due to the earth surface covered by 70% of water. Nevertheless, without a high performance generating and control system, it will not be useful and due to that, it is significant to have a good turbine control system that can use all the available potential water power [5, 11]. The control circuit is required in DC-DC converter to obtain a fixed voltage at load side because both of Pico turbine generation voltage is continuously changing in nature due to the load consumption varying all day. The constant DC-DC converter achieved by both permanently adjusting the amount of energy transferred from the Pico turbine generator that injected into the load by boost converter and fixed the load voltage with variable load resistive. Therefore, the boost converter can step up the input voltage to a higher fixed dc voltage using a combination of a pulse width modulation (PWM) boost converter and constant lock circuit. Performance parameters such as efficiency and output regulation voltage are studied to improve response system.

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The goal of this DC-DC converter design combination is to get constant 24v at the output from both variable input voltage (5-18) v which is a Pico turbine generator and variable output resistive. The internal switching inside the DC-DC converter gives rise to potential sources of noise. This noise appears itself on the output voltage as a ripple. This ripple leads to critical problems of stability and power quality. Also, the continuous dynamic interaction between the load demand consumption and the renewable energy generation make the output voltage regulation control more complicated. In [9] serve a pulse width modulation with independent time technique in this system is used to solve harmonics content in the output voltage. In [6] a photovoltaic system boost converter is studied, which converts and it gets 24v from 12v input voltage by using a 219 kHz as a switching frequency. It used a simple command scheme by using a differential amplifier which controls a 555 oscillator. The MOSFET is a switching element. In [7] is presented a study of focusing the noise generated by a boost converter, again with MOSFET, as a switch but by specific integrated circuits command. Thereare present as stochastic models and simulated score for the boost converter. In [8] gives the PI controller gain scheduled, this increase represents a function of the input voltage, so for the input voltage to the converter shows significant variation, with a fixed gain controller. Phase margin, bandwidth, and system performance studied as parameters. This paper will mainly focus on the design of constant DC-DC converter that is suitable for Pico hydro turbine generator application to get high-performance constant output voltage.

2. PICO HYDRO GENERATOR CONTROLLED VOLTAGE

Pico hydro generator needs different stages for converting the potential power in the low water flow to a useful power for supplying households.

2.1. Pico Hydro Turbine

Hydropower system converts the energy in water flows to useful forms such as electricity or mechanical work. Pico hydro is a term used for hydroelectric power generation under 5 kW. It is helpful in small remote communities that require only a small amount of electricity. The power which can be extracted from a water flow is:

$$P = \check{z} * Q * H * g * \rho \qquad (1)$$

Where ž is the efficiency of the energy conversion system, Q is total volumetric flow; H is the head, the actual height difference between the free surfaces of the reservoirs or channels upstream and downstream of a turbine, ρ is water density, and g is the gravitational constant (9.81 m/s2).

2.2. Unregulated Rectifier

An uncontrolled rectifier as shown in Figure 2.1 consists of a bridge rectifier and a filtering capacitor. The bridge rectifier converts the AC voltage (unregulated incoming AC voltage from PTG rectified) to DC voltage, and then the filtering capacitor works to remove unwanted ripple voltage to get DC voltage.

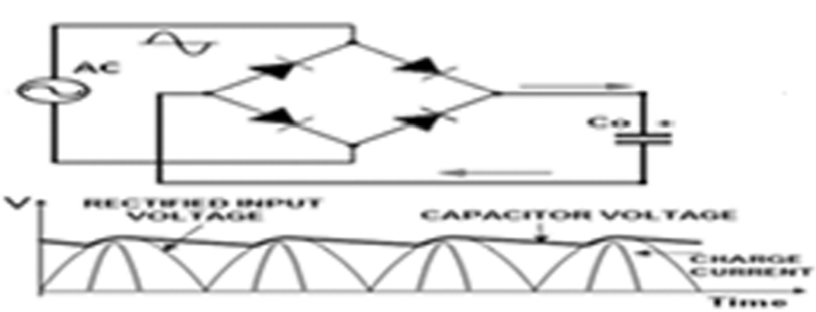

Figure2.1 Rectification the AC Output Voltage

2.3. Proposed DC-DC Converter Combination

2.3.1. PWM Boost Converter

A DC-DC boost converter used to eliminate the transformer in the system. It transforms the input voltage into a higher output voltage. The typical boost converter circuit presented in Figure 2.2. The main components are the switch, coil, capacitor, and diode. Its performance coordinated by using a PWM controller. IGBT used as a switch and by controlling the duty cycle of PWM which is feed a gate of the IGBT, it can lead to output voltage control.

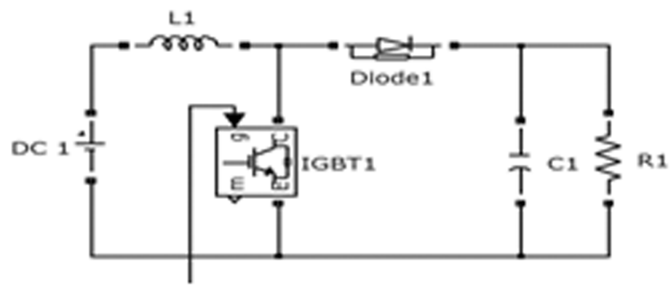

Figure 2.2: Basic Configuration of a Boost Converter

2.3.2. Constant Lock Circuit CLC

A constant lock circuit is a new circuit which follows a boost converter to make the output voltage response in a high performance efficient. The input voltage of CLC is the output boost converter, and the output voltage of CLC supplies load voltage as shown in Figure 2.3

Figure 2.4 shows the stages which are needed to convert a potential power due to water flow into available power to the load from hydro-power system.

The primary target of this DC-DC combination converter design is to get constant 24v at the output. Therefore, the load ensure fixing voltage with both variable load consumption and changing in water flow. This feature makes the control circuit accessible in many aspects such as injection power to the load.

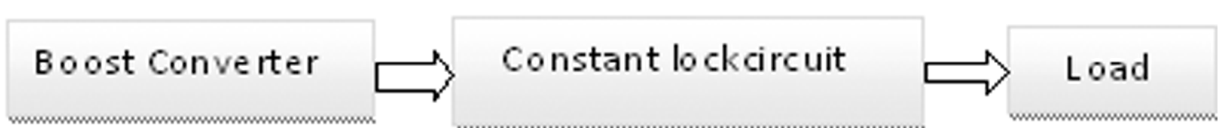

Figure 2.3: Input and Output Block for Constant Lock Circuit

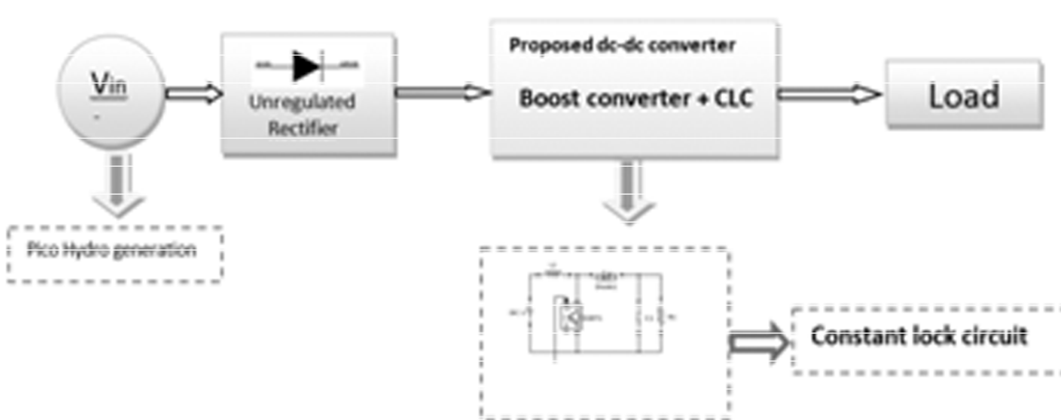

Figure 2.4: Proposed Control System Block Diagram of Pico Hydro Generator

3. METHODOLOGY

DC-DC boost converter parameters atthe steady state calculated using Eq. (1) and Eq. (2) [4, 5]. The minimum value of inductor and capacitor is given by [10]

$$L\min = \frac{Vs \times d}{fs \times \Delta IL} \tag{2}$$

Where Vs is input DC voltage, d is duty ratio; fs is switching frequency of a switch and ΔI is peak to peak ripple current through inductor = 5% IL [12],

The minimum capacitor voltage can be estimated:

$$C\min = \frac{Io \times d}{fs \times \Delta Vc} \tag{3}$$

Where Io is the average output current, and ΔVc is the ripple of the output voltage.

By assuming input voltage range (5-18 v), the output voltage (24dc v) and switching frequency 12 kHz, we get the minimum values of the inductor (0.286 mH) and capacitor (24uF) that it used to the boost converter. Based on parameters presented, A closed loop feedback boost converter is designed to get a constant output voltage for converting and regulating the variable supply voltage from (5-18) v to 24v as shown in Figure 3.1.

Boost converter's performance simulated in MATLAB Simulink Based on the proposed design parameter as shown in Figure 3.2. A closed loop feedback control system aims to get a fixed output voltage.

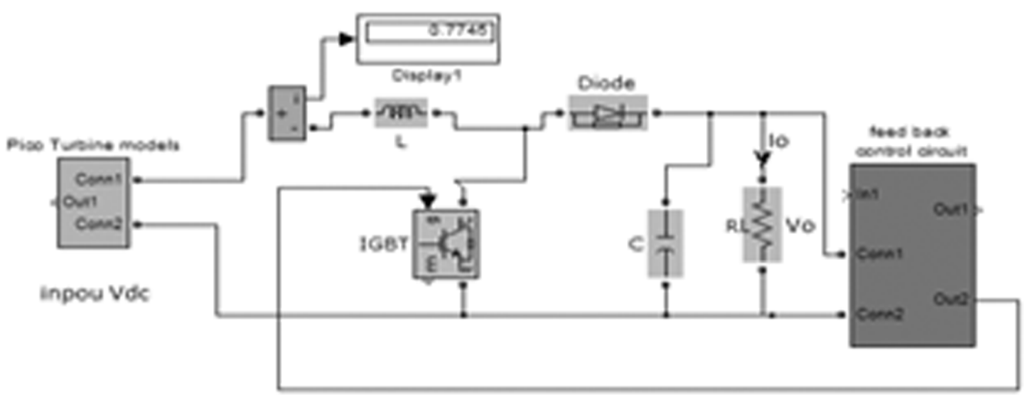

Figure 3.1: Closed Loop DC-DC Converter Boost Converter Simulink

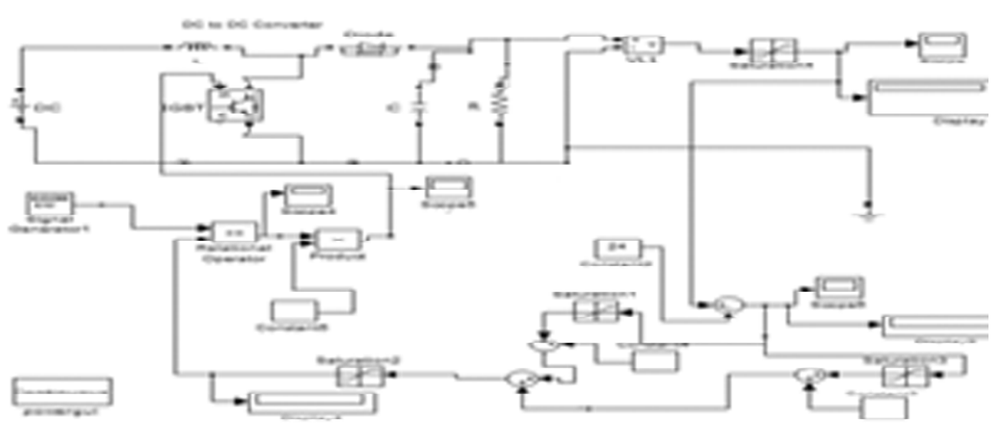

Figure 3.2: Closed Loop Control of DC-DC

Therefore, output voltage measure and compare with a control reference value 24, then the difference value is used to monitor the changing duty cycle to get a fixed output voltage with changing water flow rate

The boost converter simulation test with both different values of variable resistive load and input voltage as shown in Table 3.1

Table 3.1
Different Test Values of Variable Input Constant Voltage and Resistive Load

Input DC V	5	5	12	12	15	15	18	18
Resistive load Ω	12	6	6	3	2	1.5	1.5	1

Since the Pico turbine generator works in low water flow, and most researchers proposed the output voltage (8, 12, and 15) v. Therefore, Figure 3.3 represents the simulation of expected output voltage of Pico turbine generator during the changing inflow water passing through the Pico turbine generator models.

The DC-DC boost converter consists of switching device (transistor) which is driven by a variable PWM signal, a resistance Load R (electronic system such as DC-AC converter and loads) and (C, L, D) capacitor, inductor and diode respectively. When the converter at mode 1, switch is on, then the current flows through the L to the ground. On the contrary, in mode 2, the switch is off, the energy stored in the inductor generates a voltage with positive polarity at the anode of the diode. The capacitor voltage at this point is the sum of the inductor voltage at point one plus Vin. A closed loop feedback controller automatically adjusts the pulse width of the boost rectifier to maintain a constant dc load voltage of the desired level, despite the variations in both input voltage and load resistance. The output voltage of boost converter simulation result in Table 3.2, and Figure 3.4 explain the output voltage signal has a ripple voltage and inaccurate required 24 constant voltages.

However, the output voltage signal has a ripple voltage and inaccurate 24 constant voltage as shown in Figure 3.4 Therefore, a CLC circuit after boost converter proposed to improve output voltage. It assists to get both constant, and smooth response output voltage with a high precise voltage performance.

Table 3.2
Output Voltage of Boost Converter Simulation Results

Input DC V	5	5	12	12	15	15	18	18
Resistive Load Ω	12	6	6	3	2	1.5	1.5	1
Boost Converter o/p Voltage	24.3	24.7	24.3	24.4	24.2	24.2	24.2	24.2

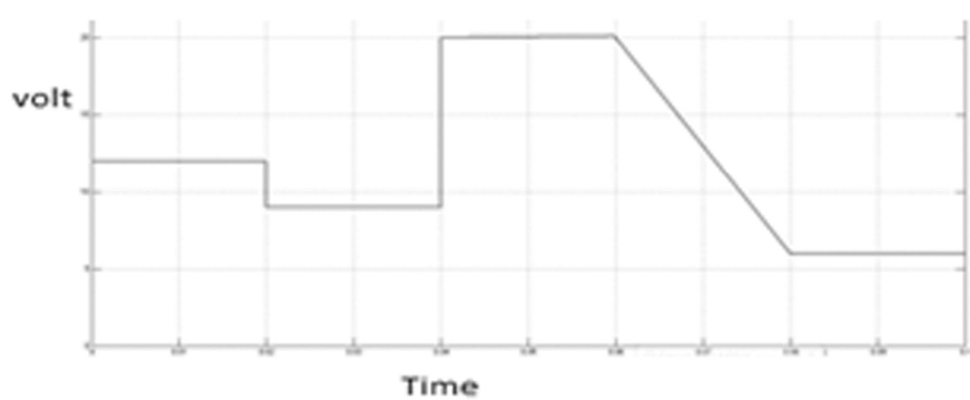

Figure 3.3: Simulation of Expected Speed Changing Inflow Water for Pico Turbine Generation Voltage Simulation Result

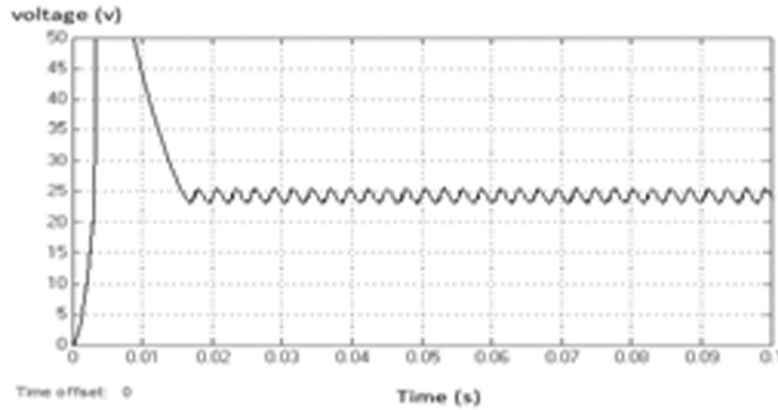

Figure 3.4: Output Voltage of Boost Converter

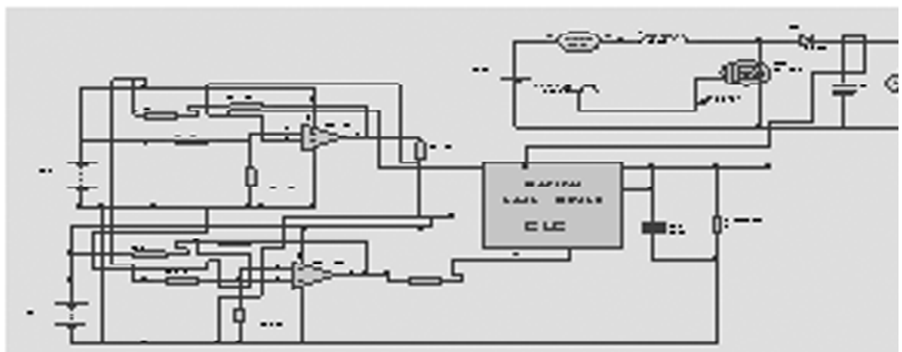

Figure 3.5: Control Circuit for CLC Design in Proteus 8 Professional

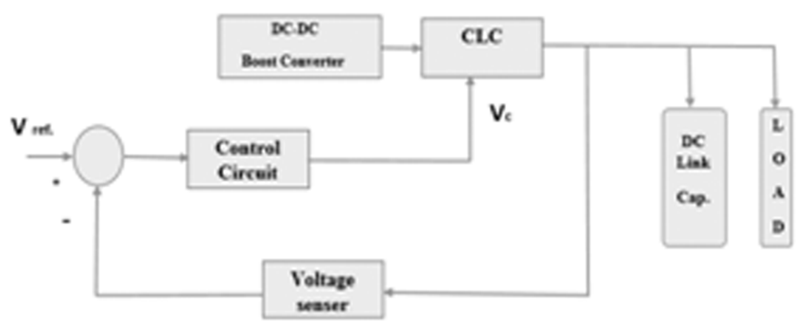

Figure 3.6: CLC Control Circuit Loop

Moreover, it overcomes any input voltage and resistive load variable. A proposed CLC circuit consists of switches, resistors, and capacitors which are connected to get a high-performance output voltage. The function of a CLC control circuit is to monitor boost converter voltage and keep a constant output voltage with high regulation. We carry the DC-DC converter design to Proteus 8 Professional program as shown in Figure 3.5 to resolve accurately a control circuit for Constant lock circuit CLC. For more clearly, Figure 3.6 shows the block diagram of the system above.

4. SIMULATION RESULTS DISCUSSION

The goal of proposed DC-DC converter combination design is to get 24v at the output from both variable input voltage (5-18) v which is a Pico turbine generator and variable resistive load. Table 4.3 clearly shows the comparison of proposed DC-DC converter output voltage results with and without CLC circuit. The results obtained to prove the CLC circuit design to get a constant 24v output voltage has been satisfied.

The closed loop control system for the proposed DC-DC converter keep the output voltage constant by firstly, changing the pulse width of switch gate after comparing output voltage and desired voltage. Secondly by using a Constant lock circuit CLC which supports DC-DC converter to improve its output voltage to be more stability. So this system firstly converts input voltage by DC-DC boost converter, secondly by a constant lock circuit which is used to get a high-performance voltage.

Figure 4.1 shows clearly the difference between two simulation signals; the red graph demonstrates smoothing response and high-performance constant output voltage after constant lock circuit. Moreover, the red graph illustrates reaching the signal to steady state before the blue graph. On the contrary, the blue graph shows the instability parameter such as steady state error and settling time of output voltage without

Table 4.3
Comparison DC-DC Converter Output Voltage With and Without CLC Circuit

Input DCVoltageV	R load&!	Vo without CLCV	Vo with CLCV
5	12	24.4	24
5	6	24.7	24
12	6	24.3	24
12	3	24.4	24
15	2	24.2	24
15	1.5	24.2	24
18	1.5	24.4	24
18	1	24.2	24

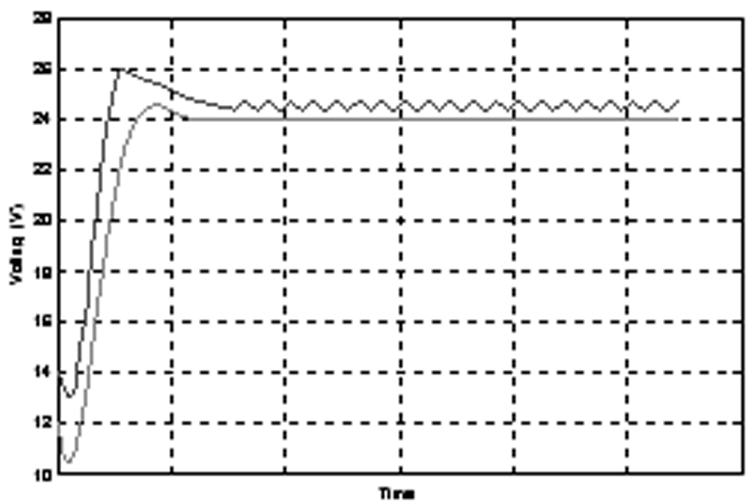

Figure 4.1: Comparison between Two Signals, Without and With CLC

Table 4.4
Calculated of CLC Efficiency

Resistive Load Ω	*VinV*	*IinA*	*VLV*	*IoA*	*Eff.%*
24	26	1.02	24	1	81.4%
12	26	2.03	24	2	81.4%
6	26	4.01	24	4	81.4%
1	34	19.8	24	24	81.4%
0.5	44	32.4	24	48	81.4%

constant lock circuit. Efficiency as one of the performance parameter, as one of performance indicator, is studied and measured of designed Constant lock circuit. Table 4.4 display precisely the voltage output is kept fixed while load resistive and the input voltage changed.

The maximum output power which can obtain is 1.1KW, and 24 v is a fixed voltage at steady state is maintained. Constant lock circuit efficiency is ranging between 94.3%-81.4 % when the load resistive varied from (24–0.5)Ω.

5. CONCLUSION

A constant DC-DC converter design is still an interesting point to achieve better output regulation. It deals with both variables the low water flow (input voltage) and resistive load (power consumption). It is a combination of DC-DC boost converter and a constant lock circuit CLC. A CLC is a new control circuit to improve the DC-DC output converter voltage. It is designed and modelled in MATLAB Simulink and PROTEUS 8 professional. The simulation results prove that the proposed plan a constant DC-DC converter was able to convert the variable input voltage, Pico hydro turbine generator voltage, from (5~18)v and maintain it at 24 V DC voltage regardless of supply voltage changing (flow rate water) and resistive load variations. Moreover, it can provide a 1.1kw with constant 24v for DC-AC inverter to supply a stable 230v AC.

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