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Neural Network Controlled Nano-Grid Technologies for Reliable Residential Grid Formation

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ABSTRACT

The development and implementation of neural network-controlled Nano-grid technologies to improve the reliability of residential grid formation. The aim is to create a self-sustaining system that can manage local energy generation and consumption to meet the needs of a community. The project will focus on developing algorithms for real-time control of power flow and voltage stability within the Nano-grid, as well as investigating the integration of renewable energy sources into the system. The proposed technology has the potential to increase the reliability and efficiency of residential power grids, reduce reliance on centralized power generation, and ultimately contribute to a more sustainable energy future. The simulation results can be evaluated by using MATLAB/Simulink Software.

Keywords: Neural network, Nano-Grid, Residential Grid, Power System Reliability, Distributed Energy Resources, Renewable Energy, Integration Smart Grid, Energy Management, Microgrids

I. INTRODUCTION

India has been working very hard over the past ten years to completely power up rural areas, yet some of the villages in states like Bihar, Uttar Pradesh, Assam, etc. still lack access to power [1]. A village is considered electrified under the Deendayal Upadhyaya Gram Jyoti Yojana 2004 Act if the ratio of the minimum number of households to the total number of households in the village is less than 10% [2]. Using electricity installations like Microgrids (MGs) or independent small power grids referred to as NG, rural areas with limited access to the grid can obtain power supply. NG is a residential grid that combines renewable energy sources (RES) and battery-based storage devices with power electronics to supply 20 kW of loads within a 5-kilometer radius of the power source [3]. Because of their simple design and dependability as a source of power, NGs have recently attracted a lot of interest from researchers and business groups around the world. Fig. 1 depicts the configuration of a practical NG structure for rural electrification.

In order to dispatch power to the load linked at the DC bus of the NG, the distributed generators (DGs) in Fig. 1's interface power electronic converters alter the voltage and current levels. With the charging and discharging process, bidirectional converters

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connected to battery storage systems balance the power levels between DGs and load. When there is excess generation, the bidirectional converter steps down the NG voltage level to charge the battery. The bidirectional converter empties the battery by increasing its terminal voltage if there is insufficient generation. In this manner, autonomously operated NG keeps the DC bus voltage level constant [4].

Solar PV and DC-type batteries are the two most prevalent components of NG. NG is therefore a DC grid by definition. The benefits of DC grids versus AC grids are briefly discussed in [5, 6]. Because there are fewer power conversion stages involved in distributing the power from each DG, the DC grid is more efficient than the AC system.

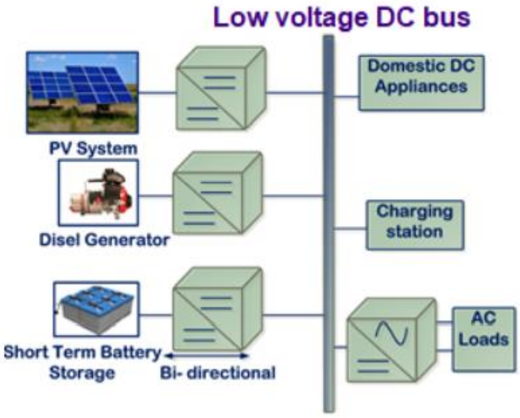

Fig. 1. Nano grid Layout

The main objective of NG is to achieve power balance between the intermittent DGs and the load. The secondary objective [7] is to control the voltage at the NG DC bus. However, the voltage at the NG DC bus is affected during the power balancing operation. As a result, proper control strategies must be used to maintain both the power balance and voltage level at the DC bus of NG. Both centralised and decentralised control systems are frequently described in the literature [8, 9]. In part II, several centralised and decentralised control strategies are compared and analysed.

The voltage and current control loops supplied at each NG source are used by the interface converters to match up the power flow between multiple DGs and loads. If the power level varies on the load side, the voltage control loop of the interface converter will establish the appropriate current level to balance the power flow between source and load based on the power availability of each source. The voltage and current levels of NG will not be changed as long as the load power levels are maintained [10]. Several different power electronic topologies are described in the literature depending on the type (AC or DC) of supply, the type of load, and the number of sources connected to the NG. An analysis of various power

There are no rotating DG dynamics taken into account by the NG structure presented in [13, 14, , , 20]. Moreover, [13, 14, 20] do not specify how an MG and multi-NG structure would share power. Moreover, the proposed control strategies in [13, 14, 20] did not examine the effect of a fast shift in the load or the disconnection of NG due to insufficient PV power and storage on the DC link voltage. A cooperative power management method (CPMS) is suggested in this work to fill the aforementioned research gaps. The suggested CPMS controls the power distribution between a small hydro power plant (SHPP) interfaced DC MG and several NG structures (110V) (380V).

In this research project, a neural network is presented. The following neural network types are frequently employed in engineering applications:

Feedforward neural network: Consists of an input layer, one or a few hidden layers, and an output layer (a typical shallow neural network)

Convolutional neural network (CNN): Deep neural network architecture widely applied to image processing and characterized by convolutional layers that shift windows across the input with nodes that share weights, abstracting the (typically image) input to feature maps.

Recurrent neural network (RNN): Neural network architecture with feedback loops that model sequential dependencies in the input, as in time series, sensor, and text data; the most popular type of RNN is a long short-term memory network (LSTM).

The organisation of the paper is as follows: The introduction of the system is depicted in Section I, the system description of the system is mentioned in section II, whereas section III describes the proposed method and section IV explains about the results that are obtained by implementing proposed method and the last section ends with conclusion.

II. SYSTEM DISCREPTION

Comparative Analysis of Various Centralized and Decentralized Control Strategies

The NG controller is essential in ensuring that the various sources are coordinated to get the best possible power flow in the NG. Several control strategies have been put out in [11–21] to maintain coordination among the various power sources and deliver the necessary power level demanded by the load. These techniques can be broadly categorised as belonging to centralised and decentralised control topologies.

A. Centralized control Method

The information obtained from multiple sources and loads through the communication network depicted in Fig. 2 is used by the central controller in this system to manage power, control voltage, and regulate the frequency of NG. A high bandwidth communication channel used by the centralised controller (CC) in Fig. 2 collects data from sensors linked to all sources and loads. The CC then makes a decision based on that data. This technique is quick and exact in terms of control. The main drawback of this control design is that any communication connection failure will result in the collapse of the entire grid. This control approach is not commercially viable since it uses high bandwidth communication channels. The decentralised control technique addresses the drawback of CC's communication breakdown.

B. Decentralized control strategy

The independent control nodes in this control scheme, depicted in Fig. 3, gather data from each source or load using separate sensors that are attached to them. This control technique is more durable and reliable than a central controller since it uses independent control nodes. Decentralized controllers do not use more expensive communication links, in contrast to centralised control schemes.

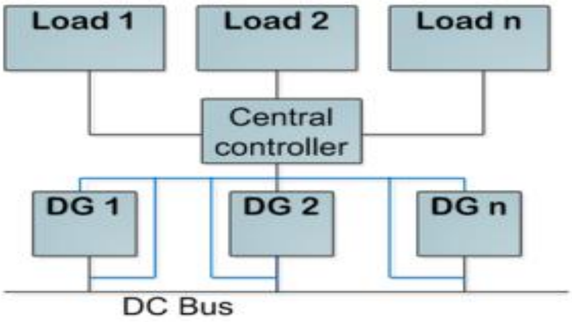

Fig. 2. Block diagram of centralized control topology

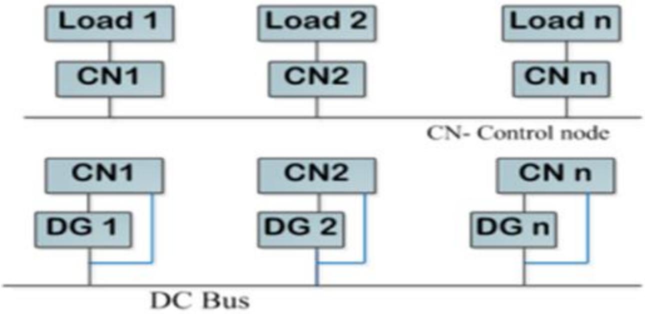

Fig. 3. Block diagram of decentralized control topology

C. Power Electronic Topologies Suitable For Ng

The interface converter technology serves as NG's structural support. The interface converter is in charge of distributing the best amount of power from intermittent RES. With closed loop control structures, they are crucial to preserving the desired voltage and frequency levels of NG.

D. Cooperative Power Management Strategy

The suggested CPMS uses a HESS and step-down converter topology, as shown in Fig. 4, to control the power flow between SHPP interfaced MG and multiple NG structures. Furthermore, MG in Fig. 4 serves its own load via CPMS without any variations in the 380V DC bus voltage. Due to its operating time constant, the SHPP in Fig. 4 cannot adapt for abrupt load power changes. According to [31], the SHPP taken into account in this research has an operating time constant of 5 seconds. The SHPP modelling is provided in [32]. Voltage fluctuations at the MG DC bus are brought on by the power imbalance between hydropower generation and suddenly shifting loads. As a result, CPMS has HESS integrated to account for these unpredictable load power variations. HESS shown in Fig. 4 is a hybrid mixture of battery and SC based energy storage devices.

The CPM in Fig. 4 keeps track of all the MG load power fluctuations and establishes the SHPP's active power delivery as a reference for the PI-based governor. The power output from SHPP will be proportional to the flow rate decided by the PI governor. The SHPP's AC power output is changed from AC to DC by the unregulated rectifier. The DC-DC converter in Fig. 4 runs in closed loop mode to match the DC MG's voltage and power levels. The multi-step-down converter topology (MSCT) depicted in Fig. 4 is used by CPMS to distribute the necessary power sought by the numerous NGs (PP1@", PP1@#), depending on the output power of SHPP (50%). The SHPP being considered in this paper has a 60 Kw power capacity. The sensing parameter designated by XXA7B' in Figure 4 permits the power to flow from MG to NGs. If XXA7B' = 1 (PPCDD 50%), the necessary power flow will be provided to NGs.

The important modelling equations of proposed MG structure are as follows.

$$P_{SHPP} = \frac{3}{2}\omega_e \varphi_m I_{sq} \quad 1$$

$$P_{HESS} = I_{SC}V_{SC} + I_{bat} \times V_{bat} = P_{HFL} + P_{LFL} \quad 2$$

VV+ = Terminal voltage of SC, *II*8F = *qq* – Stator axis current of permanent magnet synchronous generator i.e., PMSG *ωω*4= Speed of PMSG, φI = flux linkage of PMSG *PP*CGH, *PP*HGH = High and low frequency components of load power variation

The power balancing equation of DC MG is given by

$$V_{dc}C_{dc}\frac{dV_{dc}}{dt} = P_{SHPP} - P_{Load} \pm P_{HESS} \quad 3$$

CC'J = DC bus capacitance

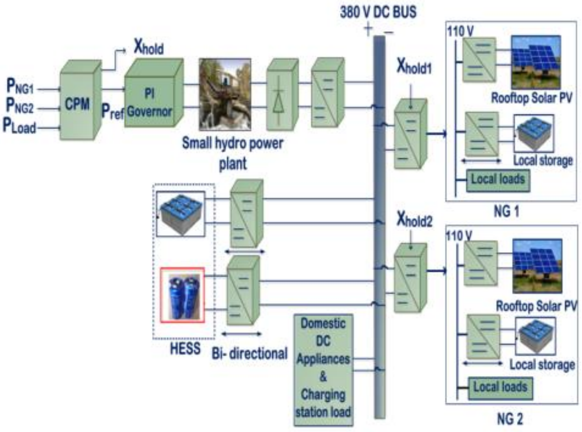

Fig. 4. Block diagram of proposed MG- multi-NG structure

III. PROPOSED METHOD

Neural networks, also known as artificial neural networks (ANNs), are a type of machine learning algorithm inspired by the structure and function of the human brain. They are designed to recognize patterns and relationships within data and make predictions based on that analysis.

A neural network consists of layers of interconnected nodes, or artificial neurons, that process input data and produce output data. Each neuron receives input from other neurons or external sources, performs a calculation, and outputs the result to other neurons. The connections between neurons are weighted, allowing the network to learn and adjust its behaviour based on the input data and desired output.

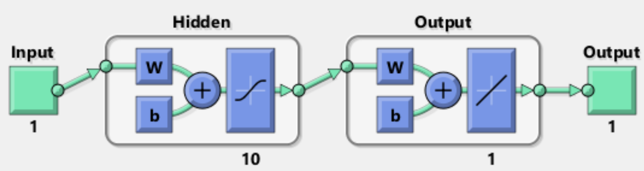

Fig. 5 NN structure

The training process of a neural network involves presenting it with a large set of input-output examples and adjusting the weights of the connections between neurons to minimize the difference between the network's predicted output and the actual output. This process is typically done through a technique called backpropagation, which involves propagating the error signal backwards through the network and adjusting the weights accordingly.

Neural networks have been successfully applied to a wide range of applications, including image and speech recognition, natural language processing, and predictive analytics. They are particularly useful in situations where traditional rule-based algorithms or mathematical models may not be effective due to the complexity or nonlinearity of the data.

IV.RESULTS AND DISCUSSION

Simulation results using PI controller and NN controller:

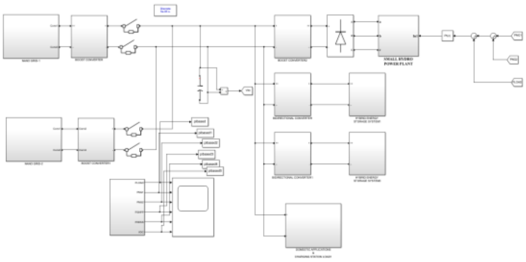

Fig. 6 Schematic diagram using PI controller

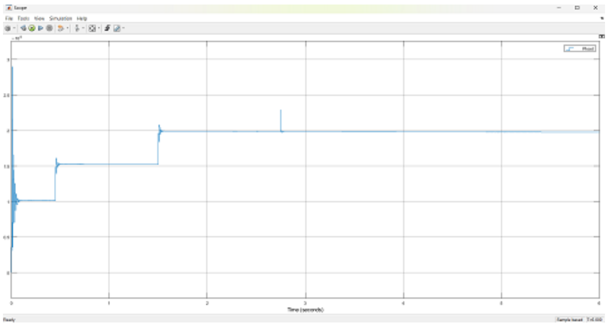

Fig.6(a) Pload

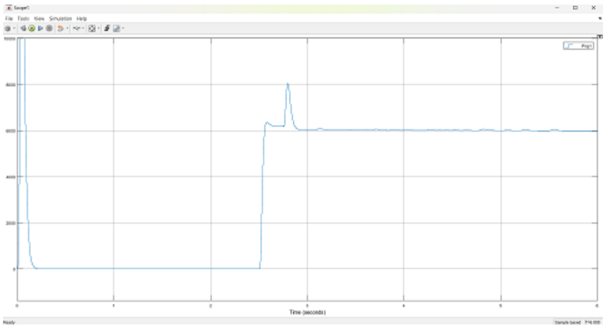

Fig.6 (b) Png1

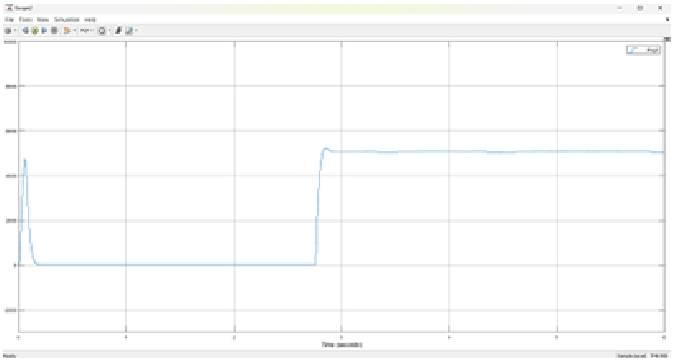

Fig.6(c) Png2

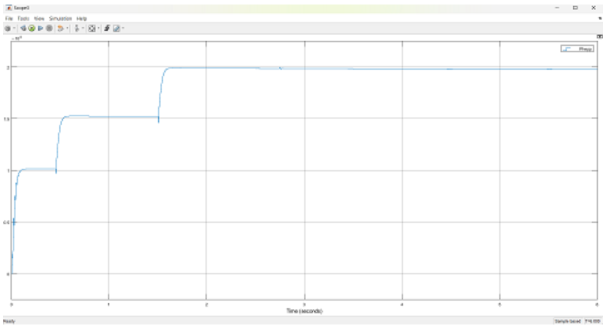

Fig.6 (d) PSHPP

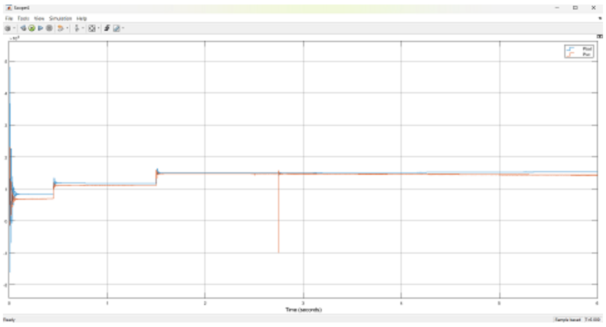

Fig.6 (e) PHESS

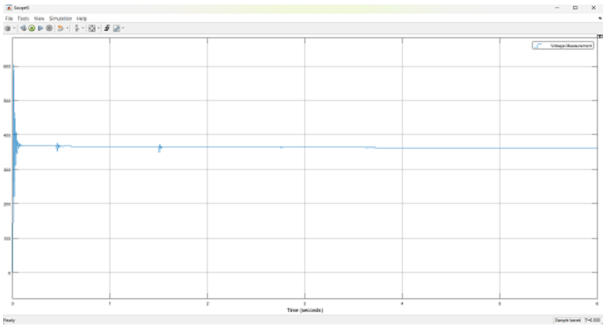

Fig.6 (f) Vdc

In Fig. 6(a), the load at the MG DC bus fluctuates by [10 15 20] kW for [0 to 6 6 to 15] secs. According to CPMS, SHPP in Fig. 6(d) has adjusted for these changes in load power using an operating time constant of 5 seconds. Considering the SHPP's available power. As a result, electricity can now pass over MSCT from MG to NG1 and NG2. NG1 and NG2 are supplied with power outputs of 6 and 5 kW, respectively, as indicated in Fig. 6(b) and (c).

By dividing the load power into high and low frequency components, HESS in Fig. 6(e) has been able to account for the abrupt load power variations at t=6 seconds, 15 seconds, and 25 seconds. Battery and SC are used to balance out the high and low frequency components, respectively. It is clear from the results above that CPMS was successful in keeping the power balance in MG. As a result, the 380V DC bus voltage is constant, as seen in Fig.6(f). so, it can be concluded from the data that CPMS has enabled unified power cooperation between an MG and several NG structures.

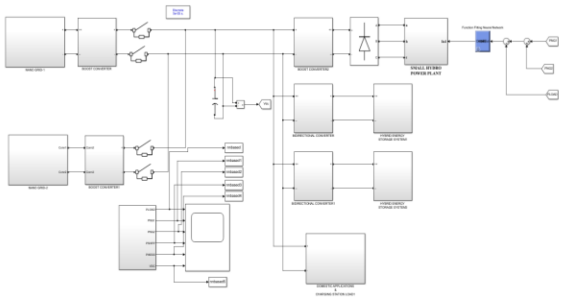

Fig. 7 Schematic diagram using NN controller

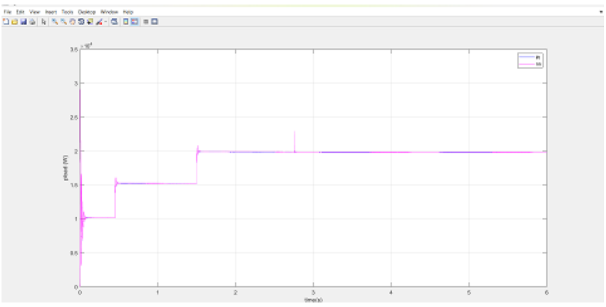

Fig.7 (a) Pload

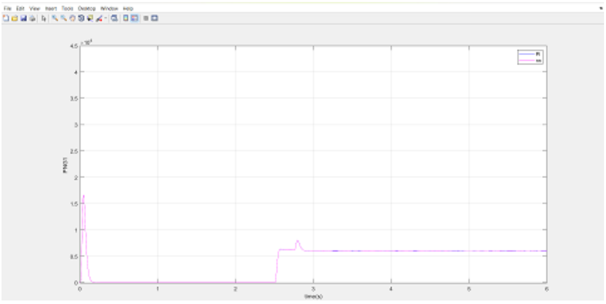

Fig.7 (b) Png1

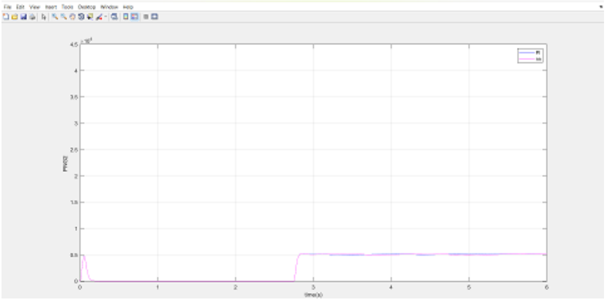

Fig.7(c)Png2

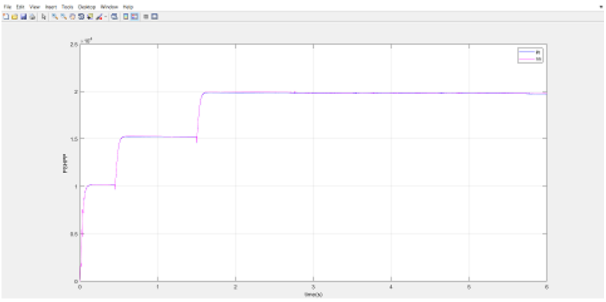

Fig.7 (d) PSHPP

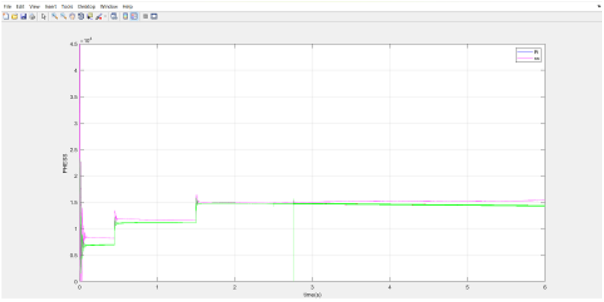

Fig.7 (e) PHESS

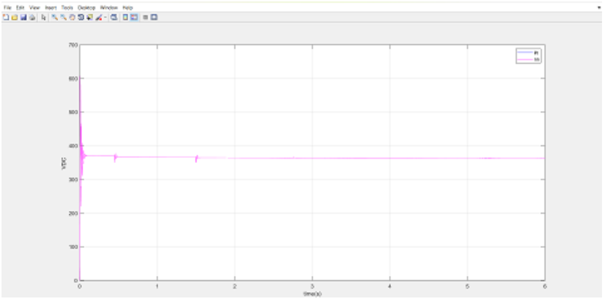

Fig.7 (f) Vdc

The above results shows the comparison between the pi and nn controller, which gives the difference in terms of magnitudes.

In Fig. 7(a), the load at the MG DC bus fluctuates by [10 15 20] kW for [0 to 6 6 to 15] secs. According to CPMS, SHPP in Fig. 7(d) has adjusted for these changes in load power using an operating time constant of 5 seconds. Considering the SHPP's available power. As a result, electricity can now pass over MSCT from MG to NG1 and NG2. NG1 and NG2 are supplied with power outputs of 6 and 5 kW, respectively, as indicated in Fig. 7(b) and (c).

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V. CONCLUSION

The Neural Network Controlled Nano-Grid Technologies for Reliable Residential Grid Formation project aims to address the challenges faced by the current electrical grid system by developing a reliable and efficient residential power grid that utilizes Nano-grids and neural network technology.

The project proposes a novel approach to power distribution and management that utilizes advanced technology to improve the reliability and efficiency of the electrical grid. By using neural network algorithms to control the distribution of power across the Nano-grid network, the system is able to adapt to changing energy demands and optimize power distribution in real-time.

Overall, the project shows promise in providing a sustainable and reliable power solution for residential areas. The use of Nano-grid technology and neural network algorithms has the potential to revolutionize the way we manage and distribute power, and could lead to a more sustainable and efficient energy future. However, further research and development are required to fully realize the potential of this technology and to overcome the challenges that arise during the implementation process.

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