Hybrid Maximum Power Point Tracking (MPPT) based on KGMO and Fast Terminal Sliding Mode-GWO

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Abstract - A comparative examination of the three MPPT algorithms used for Partial Shading Conditions, Artificial Neuronal Network (ANN) MPPT, Kinetic Gas Molecules Optimization (KGMO) MPPT and Fast Terminal Sliding Mode (FTSM-GWO) MPPT, under consistent shading circumstances, is provided in this contribution. A smart method is to use FTSM and Grey Wolf Optimization (GWO) algorithms under partly shadowed situations on a global MPP. This work now plans to include a GWO methodology that successfully sets the efficient FTSM controller parameters such that the global maximum PV device power point is monitored under partial shade. In the MATLAB setting and test performance, it is programmed for the suggested methodology of changing shade patterns dynamically. The findings have been assessed and compared with ANN, KGMO and FTSM algorithms. Unlike the others, the methodology of monitoring the global MPP in a less accurate way has been found. These methods are also evaluated and contrasted in a PV array under various partial shadowing circumstances. The superiority of FTSM-GWO controller over ANN and KGMO controllers in terms of rapidity, accuracy and stability has been clearly demonstrated.

Keywords - PV; MPPT; FTSM; GWO; KGMO.

I. INTRODUCTION

Several approaches are being utilised to maximise the energy from solar cells [1-3]. To improve the efficiency of the nanowire CdS/CdTe solar cell, Dang et al. [4] used a 10 nm thick molybdenum oxide transparent layer.

However, single and multiple axis solar trackers are also employed to improve solar insolation gathering [5-11]. Particle Swarm Optimization (PSO)[12] is one of the most used MPPT methods. Motahhir et al.[13] examine MPPT based on PV panel and power converter parameters.It is important that the P&O method has low implementation costs. This method can effectively handle both steady and dynamic environmental variables such as temperature and sun radiation[14]. Alik et al.[15] also employ this approach due of its cheap cost, simplicity, and accuracy. Moshksar et al.[16] suggested a novel MPPT algorithm to increase the installation's performance. Ramos-Hernanz et al. [17] examine three variants of the algorithm P&O in simulation and real life. Others employ the IC MPPT control method, which accurately monitors PV module temperature and follows MPP without oscillations [5].

According to Chen et al.[18-20], the IC control method enhances P&O behaviour. They developed a novel IC controller based on fuzzy logic with direct control to overcome the limitations of the traditional control algorithm IC. On the other hand, Ramos-Hernanz et al. Rezk et al. [21] compare four MPPTs: P&O, IC, Hill

Climbing (HC), and Fuzzy Logic Controller (FLC).The methods utilised by Cortajarena et al. [22] are HC, P&O, and SMC. Chaieb et al. [23]suggested a novel MPPT-based approach that is both simple and effective. The suggested technique combines the Simplifed Accelerated Particle Swarm Optimization (SAPSO) algorithm with the conventional HC algorithm.

The most common approaches are P&O and IC, concludes Li [24]. The P&O approach works effectively when the sun irradiation and temperature are stable. A simple analogue circuit or microprocessor can construct a low-cost P&O controller. However, this approach is slow to monitor the MPP and the output power oscillates around it. The IC approach outperforms the P&O algorithm but is more difficult to implement. Due of their simplicity, P&O and IC control algorithms are used by Bayod-Rujula et al [25]. In certain cases, like as fast changes in irradiance or partial shadowing of the installation, these algorithms are inefficient. Li et al. [26] introduced an MPPT control strategy using Variable Climate Parameters (VWP) that can monitor the MPP more rapidly and compares this novel algorithm to the P&O algorithms and the fuzzy control approach. However, Jamal et al.

[27] compared FTSMC to P&O and the traditional SMC algorithm. Controlling the MPPT in partial shade is one of the primary issues in PV systems. According to Mohapatra et al. [28], the choice of MPPT control method relies on the application, hardware availability, cost, convergence time, accuracy, and system dependability. Hadji et al. [29] compared a Genetic Method control algorithm to P&O and IC. Unlike Yatimi et al. [30], who compare P&O with SMC, Ramos-Hernanz et al. [31, 32] proposed a novel SMC-based control method.

The algorithm's performance was simulated and compared to actual testing. The simulated findings matched the experimental results well. MPPT may also use fuzzy logic based controllers [33, 34]. In this research, time delay voltages and currents are used. The link between variables is established or learned using fuzzy logic rules. Shahid et al. [5] suggested an incremental conductance based indoor PV system method.

The research used a temperature controller to transmit the focused light and solar PV panel temperatures to Standard Test Conditions (STC).

A MPPT based on variable step sized incremental conductance algorithm was added to the load side to provide higher power quality. This is the maximum power point of the PV panel, which is identified using a search algorithm. Recently, MPPT algorithms for outdoor solar PV systems have been proposed and implemented [35–38]. The effect of temperature on MPP of solar panels was explored by Yadav et al. [39] and Zahedi [40]. The band gap of the semiconductor material narrows as the PV material's temperature rises, providing electrons greater energy. The decreased band gap increases the carrier and thereby reduces carrier mobility. They recombine on the opposite electrode. Recombination causes saturation current.

To test the effect of open circuit voltage on solar cell temperature, Takur et al. Temperature increases with high light concentration in low concentration PV systems, as shown by Yadav et al. [41]. Yadav et al. [42] studied the effect of temperature on solar cell open circuit voltage and MPP at various temperatures.

Therefore, this article presents a comparative analysis using MPPT algorithms with ANN, KGMO and FTSM algorithms. The findings of a computer simulation (MatLab/Simulink) are used to compare the proficiency of the PV system in two separate study : I a standard PV array with uniform solar irradiation simulation . The PV system operates in two separate hardware prototype of PV array operating in two scenarios for partial shading.

The paper is structured accordingly; Section 2 defines the PV interface and the interleaved modeling.

The MPPT methods are shown in section 3, and the simulation results in section 4. In addition, there is also a presentation on the effectiveness of the MPPT algorithms and the comparative analysis. Finally, Section 5 deals with the conclusions.

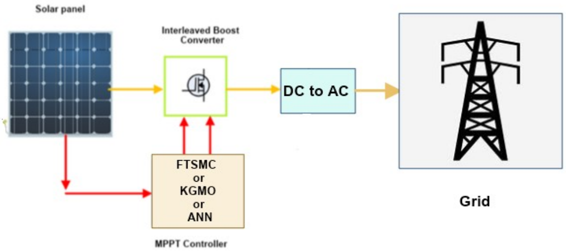


Fig. 1. Block diagram of proposed system.

II. PROPOSED SYSTEM MODELLING

A) *PV modeling*

The imposed PV cell is presented in this article Figure 2 as the current source with an anti-parallel series-related diode and parallel resistance. The circuit description and complete mathematical modeling are described in detail in [20].

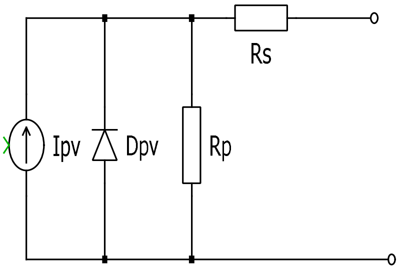


Fig. 2. PV model.

B) *Modified Interleaved Boost Converter*

The circuit configuration of the interlocking boost converter as seen in Figure 3 is to maximise the power processing capacity and to operate solar systems at maximum capacity. Interlinked topology step-up converters are working for 180-degree binary branches from each other. Typically each procedure works in the same way as the standard boost converter described above. The current increases in inductor 2, whenever two switches are turned on. At this time diode 2, which is energy-saving induction source 2, has been turned off, so that the output voltages are higher than the input voltage. If two switches are switched off, the two-diode connects and provides the capacitor with energy and load, and the two ramps with a path downstream current depending on the difference between the source and the load voltage. Apply a transition to complete the same case loop one-half of a switching time later. Due to an efficient improvement in the switching frequency, the interleaved boost converter offers a low winging strength at the input level, thereby minimizing output and input condenser filters that are comparatively high if a traditional boost transformer is used [11]. Additionally, the transfer and division of the current between the two arms leads to better stability, minimising major power losses (I^2R). Moreover, the changing of the input current between both weapons reduces dramatically power losses by shifting and dividing them (I^2R). In addition, the converter puts low stress on the passive and active components because of the existing partitions, which increase power process capacity [12][13][14][15]. In the other hand, with the connected boost converter, the sum of pology components that can lead to higher costs is improved.

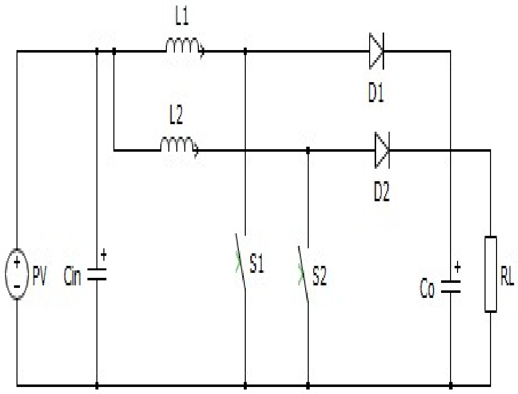


Fig. 3. Modified Interleaved boost converter.

III. MAXIMUM POWER POINT TRACKING

To harvest maximum power from the PV panel a charge controller with MPPT capability is proposed in this paper. The two broad categories of MPPT techniques are the indirect techniques and direct techniques. Indirect techniques include the fixed voltage, open circuit voltage and short circuit current methods. In this kind of tracking, simple assumption and periodic estimation of the MPPT are made with easy measurements. For example, the fixed voltage technique only adjusts the operating voltage of the solar PV module at different seasons with the assumption of higher MPP voltages in winter and lower MPP voltages in summer at the same irradiation level. This method is not accurate because of the changing of irradiation and temperature level within the same season.

$$V_{MMP} = k.V_{oc} \tag{1}$$

Another most common indirect MPPT technique is the open circuit voltage (OV) method. In this method, it is assumed that k is a constant and its value for crystalline silicon is usually to be around 0.7 to 0.8. This technique is simple and is easier to implement compared to other techniques. However the constant k is just an approximation Leading to reduced efficiency, and each time the system needs to find the new open circuit voltage (Vout) when the illumination condition changes. To find the new open circuit voltage, each time the load connected to the PV module must be disconnected causing power loss. Direct MPPT methods measure the current and voltage or power and thus are more accurate and have faster response than the indirect methods. Perturb and observe (P&O) is one of the direct MPPT techniques, which is used here with some modifications.

Typically, P&O method is used for tracking the MPP. In this technique, a minor perturbation is introduced to, cause the power variation of the PV module. The PV output power is periodically measured and compared with the previous power. If the output power increases, the same process is continued otherwise perturbation is reversed. In this algorithm perturbation is provided to the PV module or the array voltage. The PV module voltage is increased or decreased to check whether the power is increased or decreased.

When an increase in voltage leads to an increase in power, this means the operating point of the PV module is on the left of the MPP [26]. Hence further perturbation is required towards the right to reach MPP. Conversely, if an increase in voltage leads to a decrease in power, this means the operating point of the PV module is on the right of the MPP and hence further perturbation towards the left is required to reach MPP. The flow chart of the adopted FTSM algorithm for the charge controller is given in Fig. 5. When the MPPT charge controller is connected between the PV module and battery, it measures the PV and battery voltages. After measuring the battery voltage, it determines whether the battery is fully charged or not. If the battery is fully charged (12.6 V) at the battery terminal) it stops charging to prevent battery over charging. If the battery is not fully charged, it starts charging by activating the DC/DC converter. The microcontroller will then calculate the existing power Pnew at the output by measuring the voltage and current, and compare this calculated power to the previous measured power Pold. If Pnew is greater than Pold, the PWM duty cycle is increased to extract maximum power from the PV panel. If Pnew is less than Pold, the duty cycle is reduced to ensure the system to move back to the previous maximum power. This MPPT algorithm is simple, easy to implement, and low cost with high accuracy [26–28].

IV. PROPOSED TECHNIQUES

A) Fast Terminal Sliding Mode Controllers

The strategy of FTSM switches involves the tuning of a set of unknown parameter α_k ,β_k, γ_k and λ_k as shown in Figure 4. The assortment of these operative bounds is a hard and time-consuming problem. Since the iterative trials-errors procedures become ineffective, such a tuning problem is formulated as a constrained optimization program as follows :

$$\boldsymbol{Minimize\ f_i(k,t)}$$

$$\boldsymbol{k = (\alpha_i, \beta_i, \gamma_i, \lambda_i,)^T}$$

$$\boldsymbol{Subject\ to}: \quad \boldsymbol{g_1(k,t) = \delta_z - \delta_z^{max} \leq 0;\ g_2(k,t) = \delta_\emptyset - \delta_{z\emptyset}^{max} \leq 0; g_3(k,t) = \delta_\theta - \delta_\theta^{max} \leq 0\ ;\ g_4(k,t) = \delta_z - \delta_z^{max} \leq 0} \tag{2}$$

$$\boldsymbol{k_1(t) = V_{PV}(t)\ , k_2(t) = I_{PV}(t)\ ,\ k_3(t) = V_b(t)\ ,\ \ k_{ref}(t) = V_{ref}(t)} \tag{3}$$

and the structure (3) becomes

$$\dot{k}_1 = \frac{(-k_2+I_{PV})}{S_1} \tag{4}$$

$$\dot{k}_2 = f_1(k) + g_1(k)d(t) \tag{5}$$

$$\dot{k}_2 = f_2(k) + g_2(k)d(t) \tag{6}$$

Where :

$$k = [k_1 \quad k_2 \quad k_3]^T \tag{7}$$

$$\boldsymbol{f_{1(k)} = \frac{k_1}{M} - \frac{R_S}{L\left(1+\frac{R_S}{R}\right)}k_2 + \frac{1}{L}\left(\frac{R_S}{(R+R_S)} - 1\right)k_3 - \frac{V_D}{L}}$$

(8)

$$g_{1(k)} = -\frac{R_S}{L\left(1+\frac{R_S}{R}\right)}k_2 + \frac{1}{L}\left(\frac{R_S}{(R+R_S)} - 1\right)k_3 + \frac{V_D}{L} \tag{9}$$

$$f_{2(k)} = \frac{1}{S_2\left(1+\frac{R_S}{R}\right)}k_2 - \frac{1}{S_2(R+R_S)}k_3 \tag{10}$$

$$g_{2(k)} = \frac{1}{S_2\left(R+\frac{R_S}{R}\right)} k_2 \qquad (11)$$

B) KGMO-Based MPPT Algorithm

The basic principle of the Kinetic gas molecule optimization (KGMO) algorithm was suggested with the laws of gas molecules.

The molecular kinetic concept of idyllic gases is described as follows:

1. A gas consists of a group of particles that are transportable in a conventional. Motion of gas particles is based on Newton's law.
2. Particles within a gas are sockets and do not inhabit any volume.
3. The bump of particles is flexible; hence, no energy is increased or vanished throughout the bump.
4. There are no attractive or repulsive forces that exist among the particles.
5. The avg KE of a particle. velocity of particle is updated and position of particle is updated.

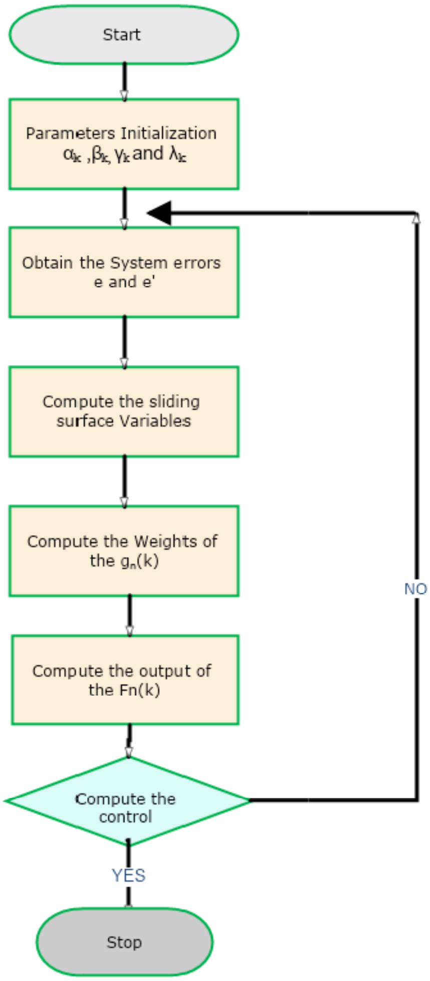


Fig. 4. Flow chart of FTSM controller.

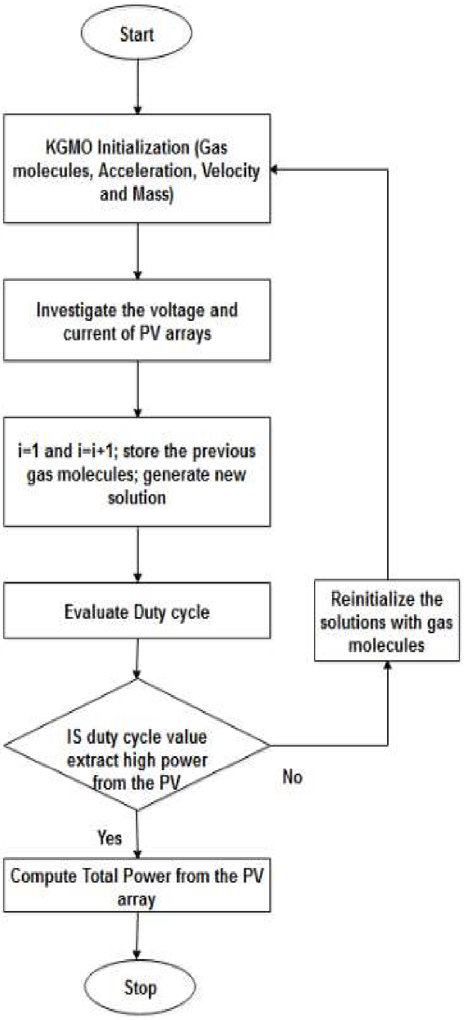


Fig. 5. Flow chart of KGMO controller

This segment outlines the kinetic optimization development with gas molecules. The gas particles move within the vessel till they meet at the part of the vessel which has the least temperature and kinetic energy (KE). Gas particles interact with each other based on low intermolecular electric forces, where the electric force is the outcome of progressive and adverse loads in the particles. In this method, each gas particle and the agent have four features: position, KE, speed and mass. The kinetics of every gas particle determines the speed and location of the gas molecule. In this method, the gas particles discover the whole research space and achieve the lowest temperature. The flowchart of KGMO algorithm is represented in Figure 5.

V. SIMULATION OUTCOMES

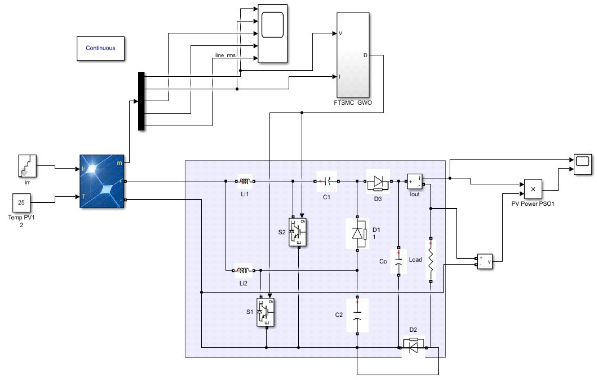
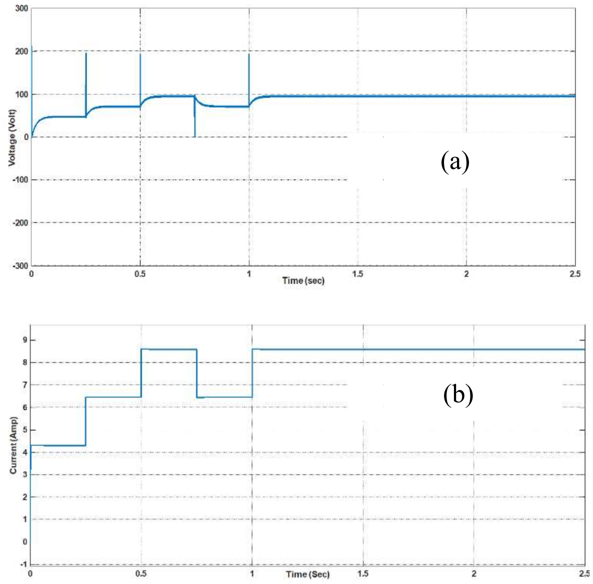


Fig. 6. Simulink model diagram of the proposed system

The efficiencies were determined according to the measured input and output power. Figure 7 represents the results for a conventional controller. As shown in Figures 8 to 10, compared to the conventional charge controller, the developed MPPT charge controllers significantly improve efficiency for each of the test time.

These results prove that maximum power is harvested from the PV module by using the MPPT charge controller. When the battery is fully charged (12.6 V), the MPPT charge controller still provide low current (5 mA) to avoid self-discharge of the battery. Hence, the overall efficiency is improved by using the FTSM- GWO MPPT charge controller. These results are also depicted in Figs. 9.



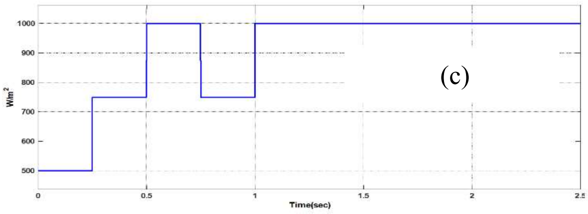


Fig. 7. Input variables (a) Input Voltage (b) Input current (c) Irradiation

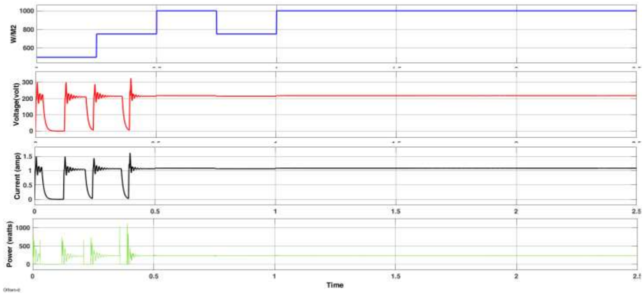


Fig. 8. ANN based MPPT Output Power, Output Voltage, Output Current (V_{in}=100, I_{in}=8.6, D=0.5 and V_{out} =217 and I_{out}=1.08 P_{out}=234)

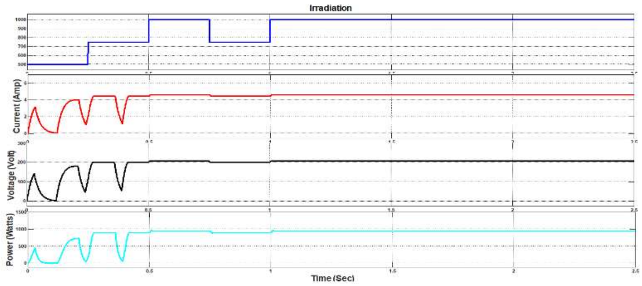


Fig. 9. KGMO based MPPT Output Power, Output Voltage, Output Current (V_{in}=100, I_{in}=8.6, D=0.5 and V_{out} =200 and I_{out}=4.3, P_{out}=860)

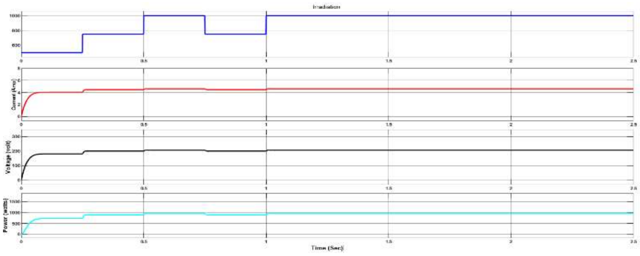


Fig. 10. FTSMC-GWO based MPPT Output Power, Output Voltage, Output Current (V_{in}=100, I_{in}=8.6, D=0.5 and V_{out} =200 and I_{out}=4.8, P_{out}=960)

VI. CONCLUSION

In this work, MPPT controllers based on KGMO and FTSM-GWO are constructed in order to extract the maximum amount of power possible from a PV module. The results of the simulation show that the FTSM approach has a short response time during transients and a low power oscillation during steady states. This was demonstrated as one of the benefits of using the technique. In addition to this, it is able to quickly follow rapid changes in the amount of solar irradiation and has a little power oscillation when the amount of solar irradiation is changing slowly. In other words, it is rather impressive. As a direct consequence of this, in contrast to the ANN, and KGMO algorithms, this approach is not only more rapid but also more accurate. In summary, the performance of the multilayer FTSM controller is satisfactory in terms of identifying and monitoring the MPP in environments in which the weather is in a state of continual flux. The future work will consider the experimental validation of the obtained results.

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