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A Hybrid of Modified DE Algorithm with FISPID MPPT Technique for Solar System

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Abstract: Currently, systems based on renewable energy sources are used to supply the rising need for electricity while reducing global warming. The primary alternative among the numerous renewable energy sources is solar energy. However, the solar panel system barely converts 30–40% of solar irradiation into electrical energy when compared to other sources. Long-term study has been conducted to assess the performance of PV systems and to look into the numerous difficulties associated to the efficient usage of solar PV systems in order to maximize output from these systems. This paper proposes an effective MPPT approach that is based on Fuzzy inference System (FIS), PID controller and Modified Differential Evolutional (MDE) algorithm. The suggested MDE-FISPIS based MPPT technique's primary goal is to supply loads with what they need to meet high energy needs. For this, we have coupled PID controller and FIS to retrieve the MPP from solar panels. Nevertheless, the fuzzy system's factors can increase system complexity; as a result, it's important to optimize the fuzzy system's parameters. For optimizing the parameters of fuzzy system, we have used Modified Differential Evolution (MDE) algorithm in the present work. Finally, using MATLAB software, the effectiveness and performance of the suggested MDE-FISPID technique are evaluated and contrasted with the conventional ACO model. The simulation results were achieved in terms of voltage, current, and power supply, and they were validated.

Key Words: *Electric Vehicles, MPPT technique, Fuzzy system etc.*

I. INTRODUCTION

When it comes to reducing carbon dioxide (CO2) emissions from burning fossil fuels, solar energy is a potential and cost-free alternative. Massive CO2 emissions have a significant impact on ecological populations through a variety of mechanisms, such as temperature increases, extreme weather events, and rising air pollution [1,2]. Due to its benefits, like the lack of fuel cost, little maintenance requirements, and silent operation, photovoltaics (PVs) has recently gained popularity as a means of electrical generating. However, because it relies so heavily on internal combustion engine cars, the transportation industry has not made much progress in reducing its emissions. CO2 emissions climbed by 13% between 2001 and 2011, with cars responsible for 25% of that growth [3]. Many nations are developing strategic strategies to replace conventional automobiles with electric vehicles (EVs) in order to minimize CO2 emissions. Also, with the world's population increasing, more electric vehicles are needed. An electric car now plays a crucial part in the electrification of transportation. Consequently, in a real sense, electric vehicles (EVs) can be a green and clean alternative to the current transportation system if the electrical energy needed to charge an EV is sourced from renewable energy sources, such as solar, wind, etc [4]. Additionally, with the added benefit of being environmentally friendly, solar panels are anticipated to be used as an electrical support component on electric vehicles. If solar panels are integrated onto the roof of these cars or if PV cells are placed on top of them, a significant amount of electrical energy can be generated and stored in the battery [5]. In a PVs, temperature and sun irradiation are two important variables that have a direct impact on the amount of electricity generated [6]. When particular air conditions are present, it has a specific operating point where its power production is at its peak. Consequently, the PVS must always run at its maximum power point (MPP). MPP tracking is the process of controlling the PVS to keep it at its MPP. Environmental factors such as sun irradiation and ambient temperature cause MPP to fluctuate continuously [7]. Consequently, MPPT are designed to deliver the most power possible from solar panels under a variety of environmental conditions. Although the power point tracking algorithms used by MPPT systems vary, their hardware is comparable.

As an illustration, the components of a typical PV system include a PV array, a DC/DC converter, loads, and an MPPT controller. The MPPT controller is used by the DC/DC converter to boost the PV system's effectiveness. One can get the most power out of a PV array by regulating the duty cycle of the inner switch to match the impedance of the PV array with that of the converter. Therefore, an effective MPPT algorithm must be able to pinpoint the precise maximum power point under a variety of meteorological circumstances [8,9], MPPT systems are a crucial component of a solar power system regardless of whether one or more power sources are used. Because photovoltaic energy is nonlinear, it is necessary to utilize an intermediary converter that uses a control scheme to operate the PV cells at their MPP in a variety of environmental situations. There were several MPPT techniques proposed, including the perturbation and observation approach [10, 11], the incremental conductance method [12], the hill-climbing method [13], and the open-circuit voltage method [14]. Moreover, For the MPPT system, some intelligent algorithms are also used, including fuzzy control, artificial neural networks, and evolutionary algorithms. A stand-alone PV system with a direct-coupled induction motor drive was designed using an artificial neural network-based, MPPT Method reported in Reference [15].

Furthermore, A unique modelling approach for PV modules was put forth by Mahamudul et al. from the University of Malaya [16] and included a boost converter and MPPT algorithm with fuzzy logic as its foundation.

The remaining sections of the paper are categorized as: Section II presented the literature survey on some of the recently proposed MPPT tracking techniques followed up by problem statement. Section III presents implemented work and its step wise detailed working. Section IV discusses various experimental results obtained for proposed work and finally section V represents and summarizes the paper.

II. RELATED WORK

Over the years, a significant number of MPPT based techniques have been proposed for extracting the maximum power from solar panels effectively and efficiently. In this section of paper, some of the recently proposed MPPT techniques are discussed. **VP Moorthy, et al, [17],** used ANN based MPPT that tracked the maximum power of solar panel. For the best possible power point monitoring, ANN utilized the Bayesian Regularization method. This method was utilized to train the neural network that controlled the duty cycle of DC-DC converters. The PV and storage systems could use the grid to get power in an emergency. The experimental results revealed the effectiveness of the suggested method. Moreover, **Dineshraj V et al. [18],** Suggested Artificial Neural Networks (ANN) that was based on MPPT to monitor the maximum power from the solar panel used in the EV charging station. DC-DC converter, solar photovoltaic (PV) and energy storage system was utilized for converter cycle and electric vehicle charging point respectively. Additionally, The Bayesian Regularization and Levenberg-Marquardt algorithms compared their efficacy. Moreover, results revealed the effectiveness of the suggested approach was assessed. The benefit of this kind of method was that it was more accurate. **Jianming Xu, et al. [19],** proposed the sectional variable step climbing (SVSC) technique and a revolutionary MPPT method. In the initial test, it was demonstrated that this photovoltaic power system accurately monitored the MPP of PV cells. In comparison to two other MPPT techniques, the climbing algorithm and the open-circuit voltage (OCV) algorithm, the second one demonstrated that SVSC was more efficient. Also, **K Habib, et al. [20],** examined the issue of solar fluctuation. This photovoltaic system could be controlled optimally, taking into consideration valid performance signs like the obtained power, the tracking speed, and the chattering level, in order to enhance overall energy efficiency and boost vehicle autonomy. This research examined the incremental technique and the particle swarm optimization (PSO) technique to achieve the solar energy's out power. The results demonstrated that the particle swarm optimization approach had excellent overall efficacy and produced an energy gain. **Ko, Shih-Hung, et al. [21],** proposed the MPPT method with modified quadratic maximization. The authors also addressed several issues with a PV system which was connected to moving vehicle. The suggested MPPT approach was validated by experimental testing in accordance with the Sandia dynamic test procedure. **Anjuru, V. et al. [22],** A DC-DC boost converter enhanced the DC voltage that the solar system generated. Additionally, The P&O (perturb & observe) technique, which was particularly simple to implement in electronic programmable circuits, was used to control these monitors. These monitors were managed using a number of MPPT techniques. The output of a PV panel was examined in this research along with the behavior of an electric car that was connected to a battery using a model that incorporated a number of environmental factors. A simulation of a prototype system using the experimental results followed the discussion of the components and functions of the proposed integrated system to demonstrate its advantages. Furthermore, **Nakir, Ismail, et al. [23**], various MPPTs with various MPP tracking methods were tried on a PV structure moving in accordance with a predetermined motion loop. A new MPP tracking algorithm practical for moving vehicles was suggested as an outcome of these studies, which also specified positive factors in every method. Under rapidly fluctuating radiations, the suggested MPPT method performed better than conventional MPPT algorithms. Moreover, under rapidly fluctuating radiations, the suggested MPPT algorithm outperformed conventional MPPT algorithms. **M. A. Khazain, et al. [24],** described the simulation of the MPPT technique based on particle swarm optimization (PSO) for PV energy conversion. The suggested MPPT was quick, scalable, precise, and effective for complete PV power tracking. Experimental results revealed that the effectiveness of the suggested MPPT method. The simulation's outcome demonstrated that this approach was feasible for real-time implementation**. Chuang, Yao Lung, et al. [25]**, the power grid was capable of charging the new battery-electric vehicles (BEVs). However, there was no other option except to use renewable energy sources (RESs) because the current fossil fuel power plant cannot produce enough power for this need. The use of a solar system, a boost converter, and a fuzzy tracking algorithm was suggested as a charging approach in this research. The primary area of research addressed in the paper under discussion was how to charge an EV without placing undue strain on the electricity infrastructure. The outcomes revealed the effectiveness of the method. In addition to this, **Fathabadi, et al. [26],** proposed quick and extremely accurate MPPT technique to maximize the conversion of solar energy into electric energy. This work contained experimental results gained from the regular operation of the built EV charging station. Experimental evidence showed that the EV charging station balanced load requirements on the local grid on overcast days in addition to producing adequate electricity to charge EVs on bright days.

From the above literatures, it is observed that a significant number of MPPT techniques have been proposed over the past few years, however, the performance of these models gets affected with several limitations. Traditional power generation systems had the drawback of being highly subject to variations, that reduced their overall effectiveness. In order to efficiently retrieve MPP, a number of academics used optimization-based methods in their research. The majority of the investigators used optimization algorithms with sluggish convergence rates and frequent traps in local minima, hence the systems were not dependable or robust. This elongates the system's processing time and makes the process of extracting MPP complex and challenging. Additionally, there are certain researches where Ant Colony Optimization (ACO) is used for the design purpose but even Among the BIMs, ACO, promises parallel processing, self-learning, plus supportive comments, among other benefits. Unfortunately, due to the lack of knowledge, the early stages of an ACO search convergence might be extremely slow. Keeping these facts in mind, a new and effective MPPT approach must be developed that can address above mentioned issues.

III. IMPLEMENTATION

In order to overcome the limitations of traditional models, a unique and effective MPPT approach is proposed in this paper wherein Fuzzy Inference system is combined with PID controller and Modified Differential Evolution. (MDE). In order to satisfy the rising load demand, the suggested model's major goal is to expand the capacity of renewable energy sources (RES) to generate power. The suggested MPPT technique is modified in two stages to accomplish this goal. The first stage of the work presents an enhanced MPPT technique that combines the Fuzzy Inference System (FIS) and a PID controller. But as we discovered from the literature review, optimising the fuzzy logic parameters is necessary to get higher efficacy. Because of this, we used differential evolution (DE), which is modified by combining it with the Levy flying technique, in the second phase of the proposed work. The Modified Differential Evolution (MDE) technique optimises or adapts the fuzzy logic's parameters to produce extremely effective results. The FLC and PID are used in combination with optimization in the proposed work for a number of reasons, one of which is that they react fast to shifting solar radiation and also help to minimise power loss, operating time, and oscillations. Additionally, as we have seen, resistive loads were the only ones employed in the past; nevertheless, in the proposed work, we will validate the model's performance using resistive loads and examine its performance using an electric vehicle (EV) as a load. Figure 1 displays the circuit diagram for the proposed Modified Differential Evolution based Fuzzy inference System PID (MDE-FISPID) coupled with a resistive load. The proposed model comprises of solar panel, MPPT method, DC DC boost converter and load resistance. Solar irradiance and temperature are two inputs that serve as input to solar panels and are converted into electrical energy. In order to harvest the most power possible from solar PV panels, a fuzzy PID-based MPPT technique is used. Error and change in error are the input signal of a fuzzy inference system, that are handled by fuzzy rules to produce the reference voltage as the output. Figure 2 depicts the graphical representation of two fuzzy inputs.

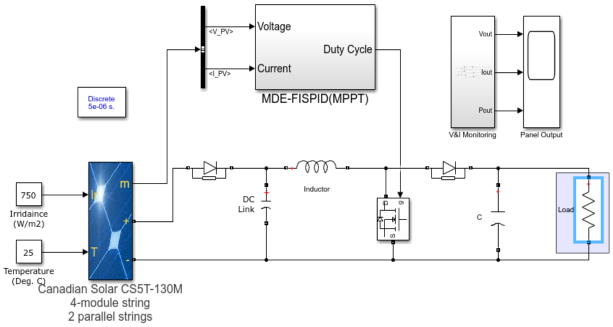
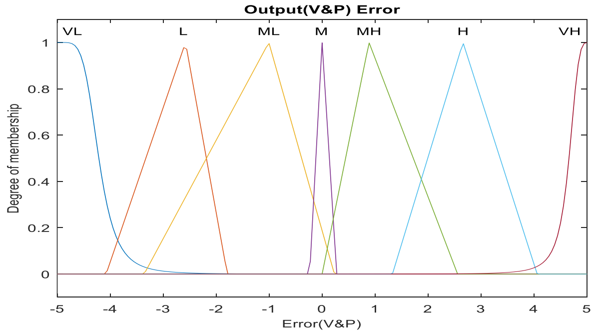
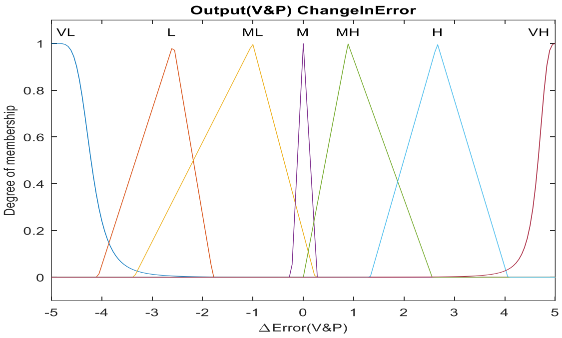


Figure 1. Proposed model with resistive load



(a)



(b)

Figure 2. Input membership functions of Fuzzy System

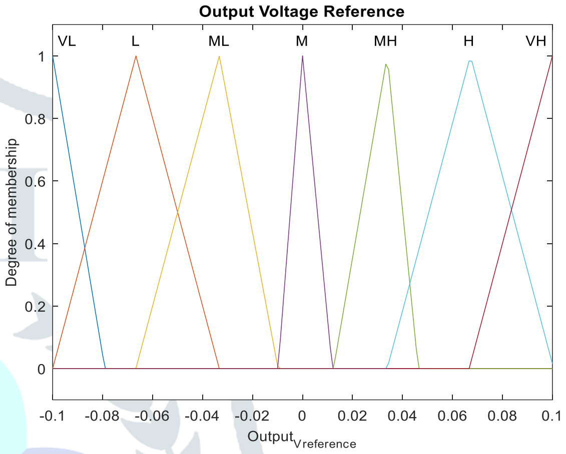


Figure 3. Output voltage reference generated by fuzzy system

The two membership functions further comprise of 7 membership variables which include VL, L, ML, M, MH, H and VH respectively, whose range lies from -5 to 5 respectively. The fuzzy system's established rule set subsequently processes the two inputs to produce a single output of reference voltage. Figure 3 displays the output function's graphical form. It consists of seven membership variables, VL, L, ML, M, MH, H, and VH, with output values that range from -0.1 to 0 to 0.1. This output reference voltage decides whether or not the specified voltage can be used to recharge an electric vehicle's batteries. The effectiveness of the suggested MDE-FISPID based MPPT solution has been evaluated in the next step of the proposed work by attaching an electric vehicle (EV) to it as a load. The lithium ion battery used in EVs needs to be charged using the suggested MDE FISPID model. Figure 4 depicts the suggested model's circuitry design with an EV linked to it.

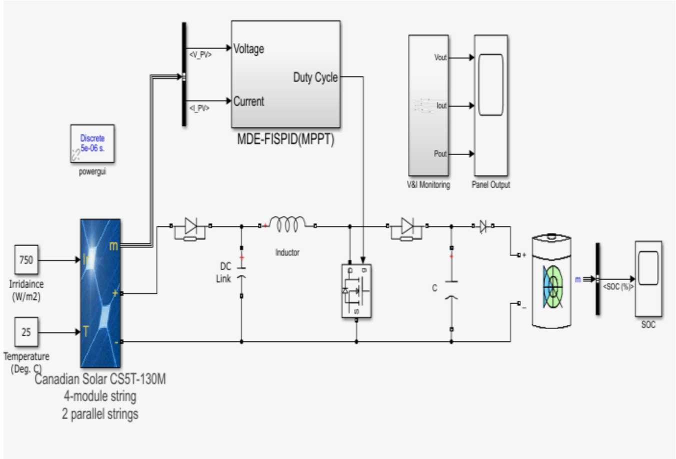


Figure 4. Proposed model with EV connected at load

Figure 4 represents the block diagram of proposed model when EV is connected to it at the load end. The models' component elements, including as solar PV panels, a DC-DC boost converter, the MPPT technology, and an EV, are similar. The suggested model tracks the MPP using the MDE-FISPID model, while the dc-dc boost converter creates and controls the duty cycles. The methodology section provides a full explanation of how the proposed power generation system operates.

3.1 Methodology

To provide an effective result, the suggested MDE-FISPID based MPPT technique goes through a number of processes. Each of the steps that is opted in proposed MDE-FISPID model is discussed in this section of paper.

Step 1: In the very beginning, we have integrated various components like solar PV panels, MPPT techniques, DC-DC converter and resistive load. The various parameters of the solar PV panel like parallel strings, maximum power, temperature, voltage and other parameters used are given in table 1.

Table 1: Solar PV panel parameters

Parameters	Values
Parallel Strings	2
Series connected modules per string	4
Module	Canadian Solar CSST-130M
Maximum power	129.94
Open circuit voltage Voc (V)	36.3
Voltage at maximum power point Vmp (V)	29.2
Temperature coefficient of VoC (%deg.C)	-0.36581
Cells per module (Ncell)	60
Short circuit current Isc (A)	4.82
Current at MPP Imp (A)	4.45
Temperature coefficient of Isc (%deg.C)	0.045996

Additionally, we have linked an electric vehicle (EV) as a load to the suggested circuit. The proposed model must be used to power the EV's lithium-ion battery. Table 2 lists the EV's various battery characteristics.

Table 2: EV battery parameters

Parameters	Values
Type	Lithium ion
Nominal Voltage (V)	100
Rated Capacity (Ah)	7
Initial state of charge (%)	50
Battery response time (s)	0.01

Step 2: As solar irradiation is not continuous, the next stage in the suggested approach is to harvest as much power as possible from solar panels. We have a PID controller (FISPID) system and a fuzzy inference system to help us with this operation. However, in order to produce effective results, the fuzzy system's parameters must be tuned. For this reason, in the suggested study, we have employed the Modified Differential Evolution (DE) technique. Levy flying approach is incorporated into the DE algorithm to modify it.

Step 3: Next, a DC-DC boost converter is used to manage the system's power in the suggested concept. A DC-DC converter's main job is to improve DC conversion from one operating voltage to the other, shielding consumer loads from voltage peaks.

Step 4: This regulated power supply is then passed to the resistive load and batteries of EV for charging purposes. The EV utilize this power for charging the batteries and providing necessary supply to loads.

Step 5: Finally, in terms of several performance dependency criteria, the effectiveness and efficiency of the proposed MDE-FISPID model are examined and contrasted with those of conventional ACO models. The following section of this paper provides an explanation of the outcomes for the same.

IV. RESULTS AND DISCUSSION

The efficiency and effectiveness of the proposed MDE-FISPID model is examined and validated in MATLAB software. The simulating outcomes were determined and validated by comparing it with traditional models in terms of voltage, current and power outputs. The detailed description of these results are given in this section of paper.

4.1 Performance Evaluation

The performance of the proposed MDE-FISPID model is firstly examined and compared with traditional ACO model in context of their voltage. The comparison graph obtained for the same are shown in figure 5. After carefully examining the graph, it is clear that the voltage produced by the conventional ACO model produces large fluctuations and spikes, which can harm the attached devices at loads. Contrarily, the voltage achieved using the suggested MDE-FISPID model is smooth and exhibits little fluctuation, making it appropriate for supplying power to loads.

The performance of the suggested MDE-FISPID paradigm and the traditional ACO model, as measured by their output current, have also been examined and compared. Figure 6 displays the final graph that was produced for the same. A smooth and continuous current line is formed by the value of current generated in the developed framework, which is observed to be about 7A from the given graph. This amount of current exhibits no variations or oscillations. On the other hand, the amount of current produced by the conventional ACO model varies greatly, with the maximum oscillating between 4 and 9 A. This extremely variable current value creates spikes, which can damage the connected devices under the load.

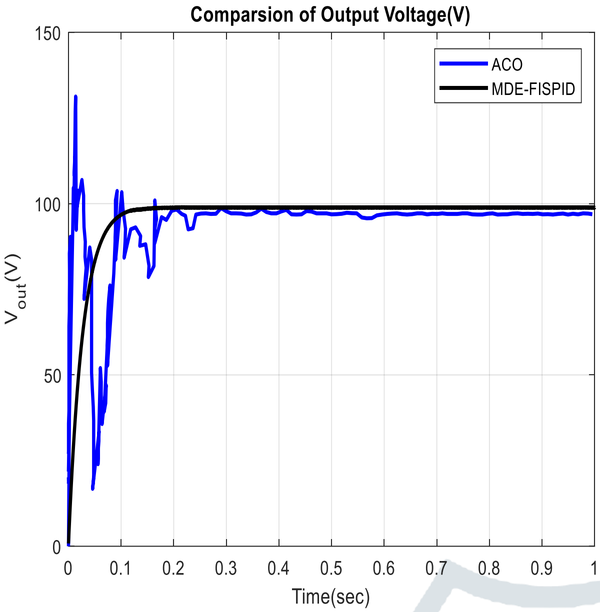


Figure 5. Comparative graph for voltage

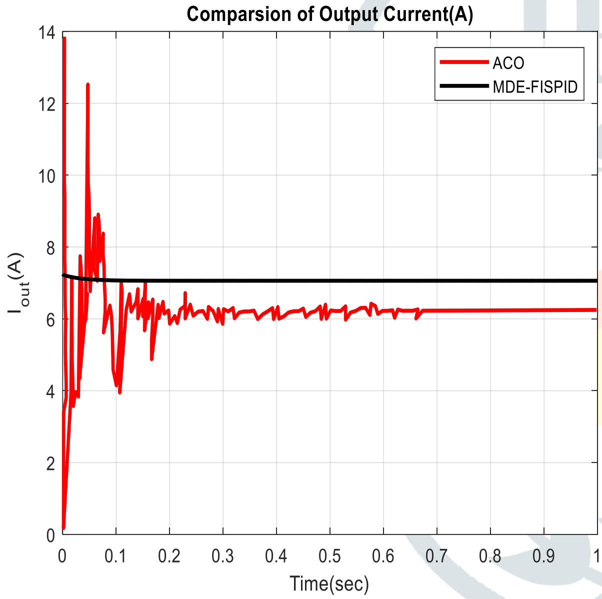


Figure 6. Comparative graph for current

In terms of its capacity to generate power, the efficiency and efficacy of the suggested MDE FISPID model are also examined and contrasted with those of the conventional ACO model. Figure 7 shows the comparison graph for the power produced by the proposed hybrid system and the conventional ACO system. After examining the provided graph, it can be seen that the power produced by the conventional ACO model varies, with a low value of 250W and a maximum value of just 610W. Whilst this is not the scenario with the proposed MDE-FISPID paradigm, the system's maximum power output can quickly approach 700W and does so without fluctuating.

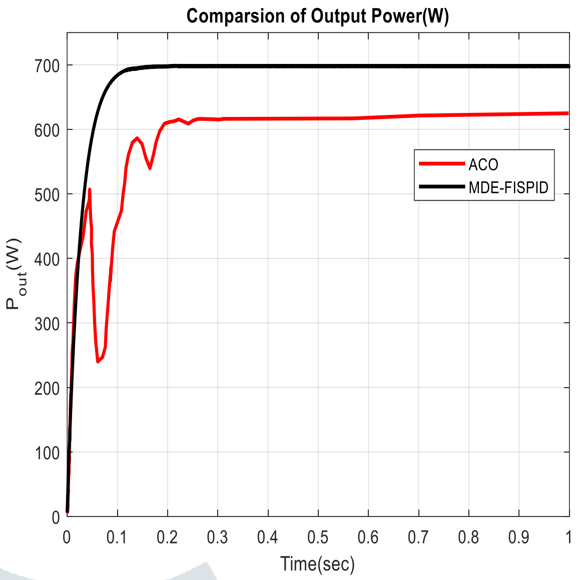


Figure 7. Comparative graph for Power

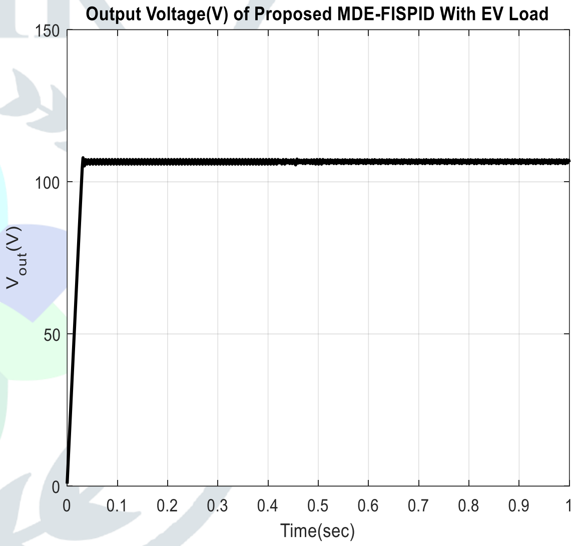
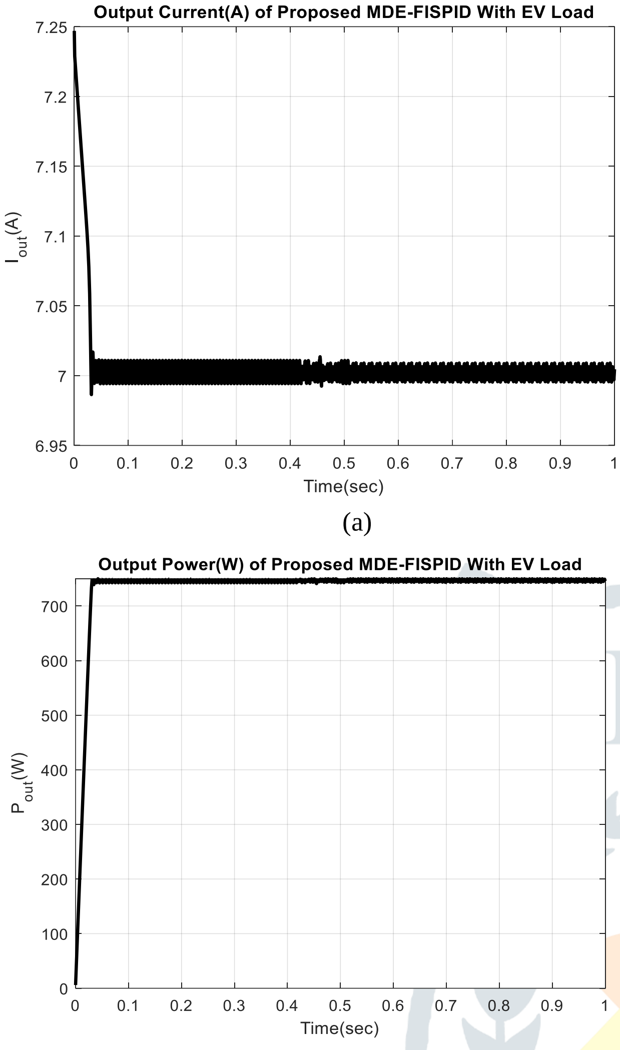


Figure 8. Output voltage of proposed MDE-FISPID model with EV load

In addition to this, we have also analysed the performance of proposed MDE-FISPID model in terms of its voltage output when EV is connected as a load. The graphical voltage curve obtained for the same is shown in figure 8. When an electric vehicle (EV) is linked to the system as a load, the voltage jumps from 0 to 110V in a matter of seconds, according to a close examination of the graph. Additionally, we've found that the voltage produced by the suggested MDE-FISPID model does not fluctuate greatly, indicating that EV batteries can be charged successfully and efficiently without suffering any damage. This demonstrates that the proposed hybrid paradigm is functional even with an EV linked to its load end.



(a)

(b)

Figure 9. Output current and Power of proposed MDE-FISPID model with EV load

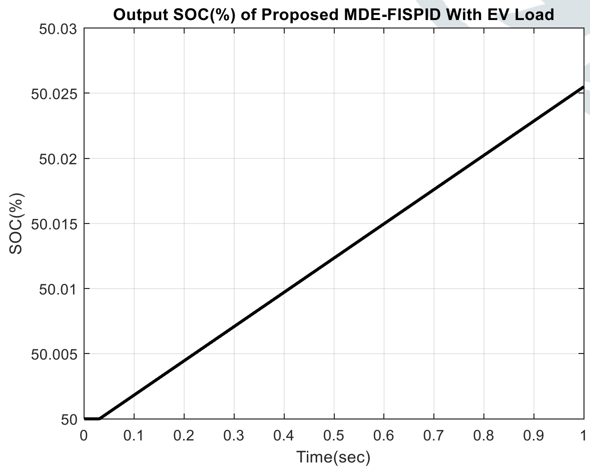


Figure 10. Battery SOC of proposed MDE-FISPID with EV load

In addition to this, the performance of proposed MDE-FISPID approach is also analyzed in terms of current and power generating abilities when EV is completed at load end. The graph obtained for the same is shown in figure 9 (a and b) respectively. It can be seen from the provided graph that the suggested MDE-FISPID Model's current value achieves a value between 7A and 7.002A. Although it must be highlighted that these oscillations are not significant enough to harm an electric vehicle's battery. On the other hand, the proposed MDE-FISPID system may create power of more than 700W that increases from 0 in a blink of an eye, according to an analysis of the graph above. At this point, the power produced by the suggested model fluctuates slightly, but not enough to degrade the batteries of EVs.

Additionally, we have examined the proposed MDE-FISPID model's effectiveness in terms of the battery's state of charge (SOC) when an electric vehicle (EV) load is linked to it, whose graph is . After carefully examining the aforementioned graph, it is clear that the battery's state of charge (SOC) starts off at 50% and increases gradually and effectively over the course of one second to reach 50.025%. The suggested hybrid MDE-FISPID model can effectively charge the batteries of EVs in a specified amount of time, as shown by the effectively charging line of SOC.

V. CONCLUSION

In this paper an effective yet convenient MPPT approach is developed that is based on Fuzzy system, PID controller and Modified DE. The effectiveness and efficiency of the suggested model are evaluated in terms of its capacity to generate voltage, current, and power. According to simulation results, the voltage of the conventional ACO model fluctuated significantly below 100 V. However, this voltage fluctuation can damage EV batteries and is therefore not advised. On the other hand, the proposed MDE-FISPID model outperforms the conventional ACO model since at 100V, the voltage it generates is stable and constant. Similarly, the current generating ability of proposed MDE-FISPID model came out to eb near 7A with no fluctuations whereas, fluctuations were extremely high in conventional ACO model. Additionally, the power value derived by using the conventional ACO model fluctuates and ranges from 0 to about 600W. While the power values in the proposed MDE-FISPID model go up to 700W with the least amount of variability. These results simulated that proposed MDE-FISPID model is more effectively and efficiently supplying power to loads while also effectively charging the batteries of EVs.

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