Computation of an Effective Hybrid DFA-SVM Approach Aimed at Adaptive PV Power Management

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Abstract: - Predominantly focussed in environmental conditions that are dynamic in nature the energy harnessed from the photovoltaic systems has to be maintained at high efficiency for which maximum power has to be extracted so a novel hybrid DFA-SVM control has been implemented using SEPIC converter. There are many algorithms to perform this function mentioned but in order to track the power at a faster rate and to avoid oscillations at the settling peak point this new methodology has been implemented. In this paper the novel algorithm used to track the peak power is Dragon Fly Algorithm-Support Vector Machines (SVMs). The algorithm is a combination of optimization and machine learning technique, so that this new methodology can incorporate both instantaneous and steady state features. The benefits of both the optimization and supervised learning technique are used to track most efficiently the maximum power with less oscillations. The DFA-SVM technique is implemented in the controller of the DC-DC converter used to regulate the supply voltage generated by the PV. The suggested MPPT's performance is demonstrated under demanding experimental conditions including temperature and solar irradiation fluctuations across the panel. To further illustrate the superiority of the suggested approach, its performance is contrasted with that of the P&O method, which is commonly employed in MPPT during difficult exams.

Key-Words: - Dragon Fly Algorithm, Support Vector Machine, Maximum Power Point Tracking, Photo Voltaic, Single-Ended Primary Inductance Converter (SEPIC), DC-DC Converter, Perturb & Observe MPPT Algorithm.

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1 Introduction

Generating power with photovoltaics is a type of energy that is renewable in nature with several benefits. Its inherent attributes that make it easy to incorporate into domestic micro-grids set it apart from other solar energy sources. Although there have been tremendous advancements in PV systems, including lower costs, increased cell efficiency, and improved building structural integration, one major drawback remains their low energy conversion efficiency, [1]. Conversely, the natural environment—which includes temperature and solar irradiation—affects how much energy photovoltaic devices generate. Therefore, in order for SEPIC converters to extract the maximum quantity of energy produced by PV modules, a control linked to maximum power point tracking should offer a suitable control to the switch of the converter used to regulate the PV power. There have been numerous studies on MPPT approaches; the most well-known ones include the incremental conductance algorithm (INC), extremum seeking control methods (ESC), and perturb and observe (P&O) techniques. These techniques typically use the PV module's immediate resultant either current or voltage in order to produce signals for control, tracking the MPP using a duty ratio, reference voltage, or reference current, [2]. The minimal computing cost and straightforward structure of the P&O approach are its advantages. The surveys give the idea algorithms rely on calculating the MPP using data that includes past temperature or radiation readings. Among these are machine learning-based systems and optimisation techniques.

To boost the PV system's efficiency, the following conditions must be satisfied: an integrated and configured MPPT algorithm and an appropriate DC-DC converter.

• Quick tracking reaction.
• There are no fluctuations near the steady-state response, or MPP.
• Reaction time to temperature variations and sun radiation.
• Easy structure that requires less calculation.

A number of studies pertaining to support vector machines (SVMs) and MPPT algorithms have been published. Machine learning techniques like Support Vector Machines (SVM) are utilized for linear regression and problem classification. ANN was trained using a vast quantity of training data produced by the SVM classifier. It is difficult to implement the suggested method on budget-friendly processors since it uses a typical support vector regression to estimate radiation concentrations via Solar and necessitates input features that are not consistently and individually generated, [3]. Using the traditional approach, the sized perturbation step was calculated for two distinct sites utilizing a solar irradiance assessment method created using SVM. However, the impacts of partial shading are not taken into account because for a particular location, the impacted dimension of steps selection is achieved offline and updated either monthly or seasonally. This paper presents a new DFA-SVM-based MPPT method. The unknown transfer function of a PV module's multivariable nonlinear P-V characteristics is estimated using the DFA-SVM. This issue is referred to as regression estimation for numerous variables in machine learning. The capacity of determining variables using fewer parameters, provide reliable forecasts even in the presence of noise and nonlinearities in the framework, and build each regressor by taking into account all of the inputs and outputs combined are the primary advantages of utilizing the DFA-SVM based approach

2 Proposed System

This work proposes a novel approach that removes irregularities about the MPP in a constant state when computing a PV module's MPP using numerous inputs to a single-output control. For training the SVM , the Dragon Fly Algorithm provides a heuristic technique that is significantly more successful. The SVM may not be trained as successfully because it only relies on the algorithm's capacity to monitor MPP. However, when DFA-SVM is employed for MPP monitoring, it enables a substantially faster rate of convergence. Therefore, the DFA technique is included to avoid all of the aforementioned shortcomings, [4]. It is possible to incorporate the suggested MPPT algorithm with the DC-DC SEPIC converter's double loop control in a low-cost commercial DSC. Through simulations, the suggested method's performance has been confirmed, demonstrating good repeatability and precision. The MPPT control schematic for a photovoltaic module uses a SEPIC converter to charge the load shown in Figure 1. The module uses voltage and current to perform conversion of solar photons into electrical energy, charging the load. The P-V & I-V curve for the panel is shown for various irradiance & surrounding temperatures. The SEPIC converter architecture is selected for use as a DC-DC converter in this work. Models are included for various irradiation conditions shown in Figure 2.

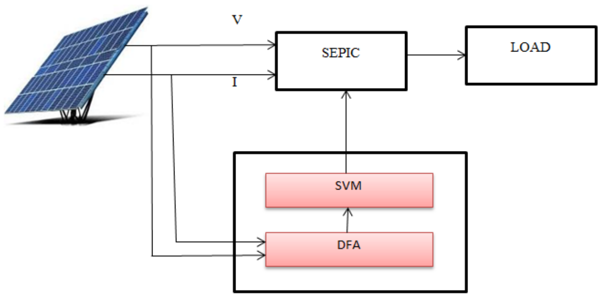

Fig. 1: An overview of the proposed DFA-SVM MPPT scheme

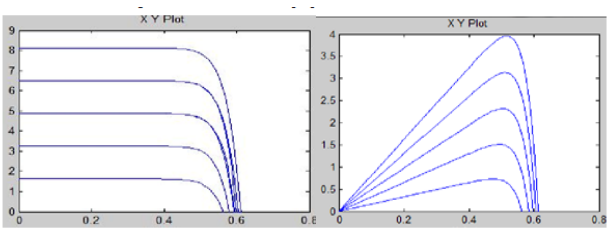

Fig. 2: IV and PV Characteristics of the PV panel

3 DC-DC Converter

A SEPIC (Single Ended Primary Inductor Converter) is the type of DC-DC converter. It is possible to effectively convert a DC voltage to a different DC voltage level using a switching power supply, or SEPIC. This specific type of buck-boost converter may adjust the input voltage to produce the desired output voltage by stepping it up or down. An inductor, a capacitor, and two switches—typically MOSFETs—connected in a certain arrangement make up the SEPIC converter topology, as seen in Figure 3. The inductor and the output capacitor are both charged via a diode when the switch linked to the input voltage is switched on. The regulated output expected from converter is entirely governed by the controller which controls the signal set to the MOSFET. The regulated output can be boosted or reduced by the SEPIC converter by controlling the pulse signal given. Moreover SEPIC gives a perfect isolation even without using an isolation transformer for the source and load. which is an additional benefit for using this converter, [5]. As a result this converter design is s desirable one, as it delivers the required output in numerous conditions. The list of components used along with its specifications for the design of SEPIC converter is shown in Table 1.

When the MOSFET is kept in ON condition, the first inductor receives power from the PV supply. The other inductor absorbs energy from C1 or the linking capacitor, while the output capacitor remains to supply the load. When the MOSFET is kept activated, the first capacitor charges the second inductor, and the supply charges the input inductor. During this period, the load capacitor receives no energy.

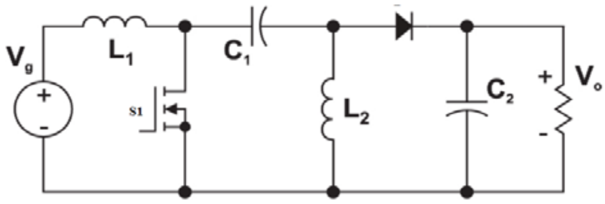

Fig. 3: SEPIC Converter Topology

The energy contained in the inductor is transferred to when the power switch is switched off. The diode facilitates the transmission of energy from the stored energy, providing the load with energy, [6]. At this point, the load is also linked to the second inductor. Because it experiences a current pulse during the off-time, the output capacitor is by nature noisier than a buck converter. The duty cycle L & C in the circuit are the main factors that determine the extent to which the SEPIC converters raise or lower the voltage.

Table 1.Converter Components Values

Parameter	Values
Inductor L1	25 μH
Capacitor C1	10 μF
Resistor	1000 Ω
Duty Cycle	61.54 %
Inductor L2	380 mH
Capacitor C2	47 μF

4 MPPT Algorithm Techniques

The aim for maximising the efficiency and power extracted from PV, the maximum power point tracking regulator is used to track voltage, current to maximise power output extracted from the panel, [7].

4.1 Perturb and Observe Algorithm

The most predominant tracking method for PV panel that tracks MPP is the perturb and observe algorithm, [8]. This technique finds the peak power where the maximum power output can be achieved by changing the panel's voltage and current.

The technique relies on frequent monitoring and calculation of the power. The panel parameters are regularly increased or decreased by the tracker. If one change leads to an increase in the output, the next one is generated in the similar direction, [9].

The operation is repeated while varying the duty cycle of the SEPIC until the maximum power point is attained. The perturb and observe algorithm's fundamental steps are as follows, with the flow chart displayed in Figure 4:

1. Check the PV panel's voltage and current.
2. Gradually raise the voltage and gauge the panel's power output.
3. If the power output has increased, measure the power output at each step while keeping the voltage increased in the same direction.
4. Reverse the direction of the voltage adjustment and repeat step 3 if the power output has dropped.
5. Take note of the electrical voltage and current values once the power point's highest value is attained and use them as the panel's set point.
6. To guarantee that the panel is always running at its maximum power point, repeat the procedure on a regular basis.

The limitations of this traditional method include its inability to follow MPP during significant changes in the insolation level and its on-going oscillation around MPP. But the advantages of this approach are its low cost, easy implementation, and straightforward structure.

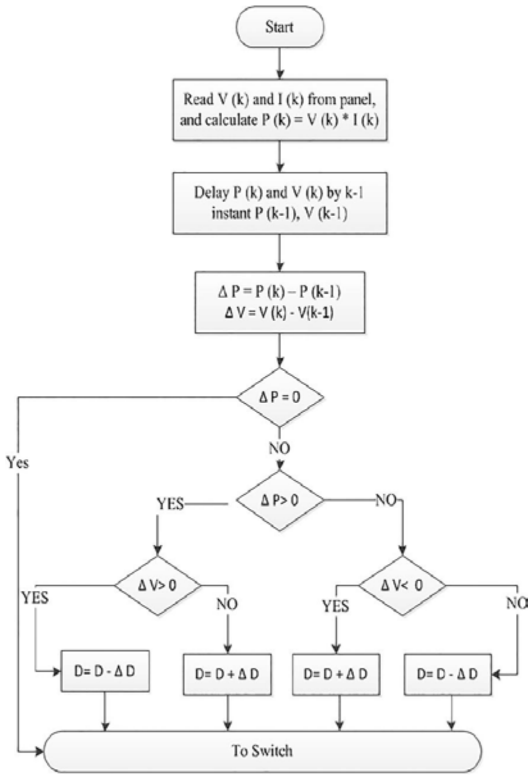

Fig. 4: Perturb & Observe MPPT Algorithm

4.2 The Proposed DFA-SVM MPPT Technique

This paper presents a heuristic technique for training the SVM using the Dragon Fly Algorithm, which is significantly more successful. Machine Learning Techniques always yields results which is far better than the traditional methods [10], [11], [12], [13], [14]. The SVM alone may not be trained as successfully because it only relies on the SVM and the algorithm's capacity to monitor MPP. However, when DFA & SVM are employed for MPP monitoring, it enables a substantially faster rate of convergence.

Therefore, the DFA technique is included to avoid all of the aforementioned shortcomings. One limitation of the SVM is that training data that is not sufficiently exact and optimized can lead to improper training of the SVM. Different environmental conditions could lead to misbehavior from the structure and system malfunctions, which would make the system, operate inefficiently. DFA was chosen in this work because it monitors data faster, is simpler, and has a greater rate of convergence than other metaheuristic techniques. Furthermore, the SVM is included since it is considerably simpler to build and can track the MPP, preventing oscillations and variations in power during the first stage, and has a better grasp of the system with the right training. In order to collect the dataset with the voltage, current, and duty cycle parameter that correlate to the system performance with regard to various scenarios, the DFA stimulates the PV system under a variety of climatic situations. The way SVM operates is by identifying the hyperplane with the greatest margin that divides the two classes of data points. Stated differently, it seeks to identify the optimal line or plane that divides the two classes in order to maximize the distance between the line/plane and the nearest data points for each class. The kernel trick is a technique that allows the SVM algorithm to handle non-linearly separable data. The input data is mapped via a kernel trick on a multi-dimensional sector which can be segregated using hyperplane.

As a result, the data points can be divided using a non-linear border using SVM. Here, swarm intelligence-based DFA is used to tackle nonlinear problems.

Within a swarm, there are two different kinds of movement: dynamic and static. A static swarm is made up of a few DF searching for food in a small region. They can only move in little leaps that resemble the exploitation of search space. The acronym of the equations from (1) to (7) is given in Table 2.

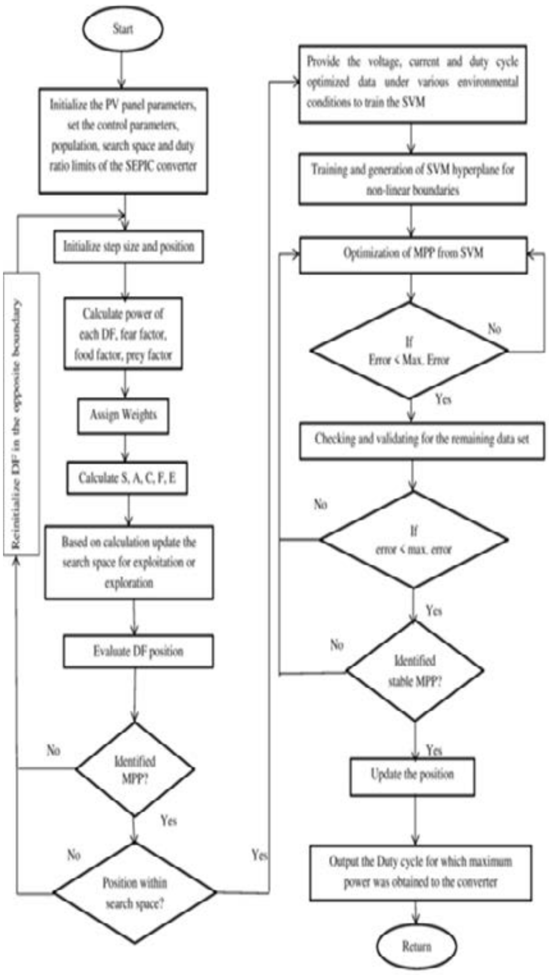

Fig. 5: Flow Diagram of the Proposed MPPT

$$S_i = -\sum_{K=1}^{N}(X - X_k), \quad (1)$$

$$A_i = \frac{\sum_{k=1}^{N} V_k}{N}, \quad (2)$$

$$C_i = \frac{\sum_{k=1}^{N} x_k}{N} - X. \quad (3)$$

$$F_i = X_{Food} - X. \quad (4)$$

$$E_i = X_{enemy} + X. \quad (5)$$

$$X_i = X_i + \Delta X_i, \quad (6)$$

$$\Delta X_i = (sS_i + \alpha A_i + cC_i + fF_i + eE_i) + w\Delta X_i \quad (7)$$

Table 2.Equation Symbols

Parameter	Acronym
S_i	Separation factor of i^{th} DF
s	Separation factor
a	Alignment factor
A_i	Alignment of i^{th} DF
c	Cohesiveness factor
C_i	Cohesion of i^{th} DF
f	Food factor
F_i	Food attraction
e	Enemy factor
E_i W ΔX_i	Enemy location Inertial weight Step size of DF

Thus by implementing DFA the generated dataset from the optimization algorithm is fed into the SVM to train the system and modify the structure's parameters through DFA, which culminates in the creation of a precise and effective control strategy, as illustrated on t he following Figure 5.

5 Outcome and Discussions

The tool MATLAB Simulink is utilised for system assessment and analysis. The system is tested, maintained, and contrasted with the use of P&O MPPT and the hybrid algorithm in order to analyse and evaluate its performance in a variety of working scenarios. The Hybrid Dragon Fly and SVM algorithm, which is interfaced with a SEPIC for normalizing solar supply and output the same to the load, allows the PV system to extract MPP under a variety of climatic conditions.

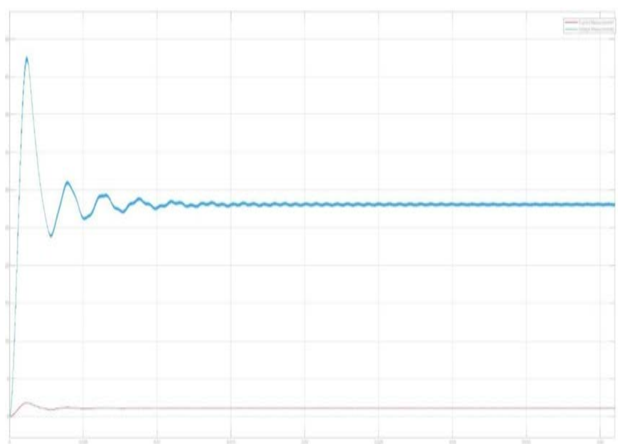

Fig. 6: Output Voltage and Current measurement using P&O MPPT Technique

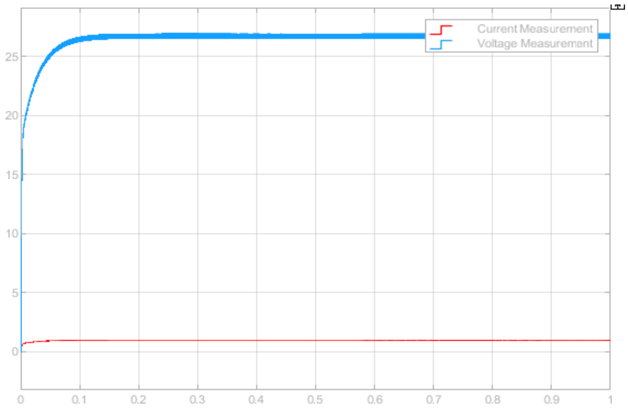

Fig. 7: Output Voltage and Current measurement using DFA-SVM MPPT Technique

The Figure 6 and Figure 7 depicts the output when P&O and DFA-SVM MPPT methodology are used respectively. The SEPIC alongwith DFA-SVM tracker has several added advantages when compared with the old controllers. It is more accurate, efficient, and capable of adapting to change in environmental conditions.

The design and implementation of the system is complex when compared with traditional controllers. The use of machine learning algorithms requires much more computational resources, which could increase the overall cost of the system, [15]. Overall, the SEPIC converter with hybrid MPPT controller shows great potential in improving the performance of solar panel systems. The following inferences were extracted while analyzing the system which is shown in Table 3 (Appendix) and Table 4.

Thus by the implementation of DFA-SVM based system the following benefits are achieved:

- Maximizing the output of solar PV arrays in a wide range of environmental conditions
- Faster tracking when compared with other traditional strategies as hybrid approach has been proven to settle faster in MPP
- Faster output tracking which shows that the system can respond more quickly to environmental conditions and load requirements.

Table 4 Comparison of DFA-SVM and P&O

Conditions	Voltage Ripple	Power Efficiency	Settling time
With P&O MPPT	3.11	81.35%	1.0
With DFA-SVM MPPT	3.0189	89.81%	0.2

- A combination of AI based algorithms (such as SVM) and optimization algorithms (such as DFA) allows the method to combine the benefits of both techniques to create a more complete and effective MPPT strategy
- Enhanced system effectiveness by faster response time providing tangible benefits for end users
- Higher yields due to improved reliability which effects in lower costs over time

The hardware implementation using the hybrid MPPT was done which is depicted in Figure 8.

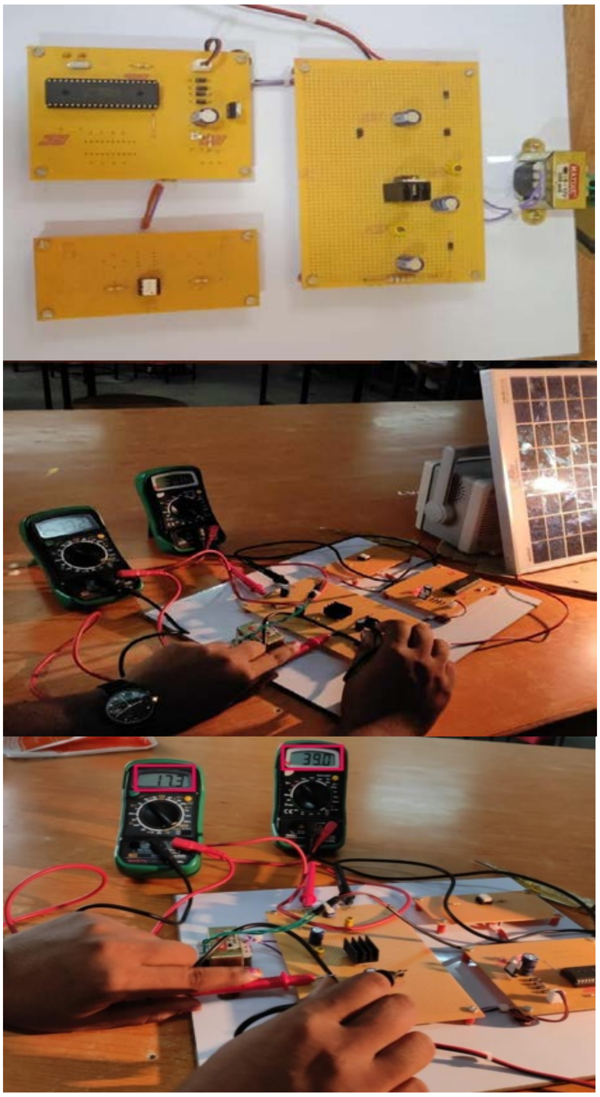
Fig. 8: Hardware implementation

6 Conclusion

This paper uses a novel hybrid Dragon Fly Algorithm-SVM MPPT technique to maximize output in a range of environmental circumstances. After a comparison between the hybrid methodology and the traditional strategy, it was found that the hybrid approach settled in the MPP and tracked the output at a faster rate. In order to enhance the solar PV array's performance, this method recognizes the benefits of both artificial intelligence-based algorithms and optimization algorithms. The DFA-SVM-based MPPT controller enhances system effectiveness and benefits end users, with faster response times compared to traditional P&O algorithms. This work will significantly impact the development of more reliable and efficient solar systems for renewable energy applications, enhancing overall system efficiency. The future work that can be done is to refine the hybrid algorithm's performance metrics (like convergence speed, efficiency, etc.,) and include more parameters to increase the robustness of the system over a wide range of environmental conditions.

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APPENDIX

Table 3. Comparison of DFA-SVM and P&O parameters

Category	**DFA-SVM - MPPT**	**P&O - MPPT**
Accuracy	DFA-SVM-based MPPT techniques are known for their high accuracy in MPP. DFA-SVM models can learn complex relationships between input features (such as temperature, irradiance, and voltage) and output power, leading to precise MPPT.	P&O algorithm MPPT controllers are simpler but may have slightly lower accuracy due to their incremental adjustment approach.
Response speed	DFA-SVM-based MPPT techniques may have a slower response due to the need for model training and prediction.	P&O algorithm MPPT controllers are generally faster in responding to changing environmental conditions. They continuously perturb the operating point and observe the resulting power change to determine the direction of adjustment.
Robustness	DFA-SVM-based MPPT techniques can handle nonlinear and non-ideal characteristics of PV modules better than the P&O algorithm, making them more robust in challenging operating conditions.	P&O algorithm MPPT controllers rely on assumptions about the PV system's behavior, which can result in suboptimal performance under certain circumstances.
Complexity	DFA-SVM-based MPPT techniques, on the other hand, involve more complex mathematical models and require training data, feature extraction, and model validation.	P&O algorithm MPPT controllers are relatively simple and require fewer computational resources. They are easier to implement and understand, making them suitable for low-cost and resource-constrained applications.
Training data availability	DFA-SVM-based MPPT techniques rely on historical training data to build accurate models. If extensive training data is available that represents a wide range of operating conditions, DFA-SVM-based techniques can provide excellent performance.	However, obtaining representative training data can be challenging in some cases.

Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The authors equally contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself

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Conflict of Interest

The authors have no conflicts of interest to declare.