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Soft computing technique for Harmonic Mitigation of Enhancing Grid-Integrated Photovoltaic (PV) System Power Quality.

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Abstract: This abstract explores the use of soft computing techniques for harmonic mitigation in renewable energy integration, particularly for photovoltaic (PV) systems in power grids. Traditional methods often fail to effectively mitigate harmonics, leading to system performance compromise and grid instability. Soft computing's adaptability and ability to handle complex systems offer promising solutions. The study explores the use of soft computing techniques like artificial neural networks, fuzzy logic, and genetic algorithms to mitigate harmonics in PV systems. ANNs learn complex patterns, fuzzy logic handles uncertain data, and genetic algorithms optimize mitigation strategies for varying grid conditions and system dynamics. The study demonstrates the effectiveness of soft computing-based harmonic mitigation techniques in improving power quality indices like total harmonic distortion and voltage stability. It emphasizes the importance of integrating advanced computational approaches in PV systems for seamless grid integration and promoting sustainable renewable energy integration.

Key Word: Renewable Energy sources, PV systems, harmonics, fuzzy logic controller, ANNs.

I. Introduction

Solar energy is a popular renewable resource due to its low maintenance requirements, noise and fuel costs, and air pollution. However, when integrated into the grid, it can negatively impact power quality. A connected solar PV system converts DC into alternating current, serving as a backup electrical supply. To raise PV voltage above the grid's maximum, a DC-DC converter is used. The use of power converters in RES can introduce harmonics, distorting source voltage, and malfunctioning control devices. To reduce harmonics, techniques like SAPF are used. Power electrical equipment responds quickly and operates with flexibility. Researchers are exploring new optimization techniques like Fuzzy logic, Artificial Intelligence, and Artificial Bee Colony Optimization to improve power quality and reliability. These methods aim to maintain the quality of electricity.

II. Literature review

There are power quality issues when photovoltaic (PV) systems are integrated into power networks, especially with harmonic distortion. Because PV systems are dynamic and nonlinear, traditional harmonic mitigation techniques like synchronous compensators and passive filters frequently show limitations in [2] their ability to properly handle these characteristics. Consequently, to improve harmonic mitigation techniques, academics have been turning more and more to soft computing techniques. The potential [2] of Artificial Neural Networks (ANNs) to learn intricate patterns present in harmonic distortion has attracted a lot of interest. Research like this one has shown how well artificial neural networks (ANNs) detect and mitigate harmonics, which raises power quality indices. Moreover, fuzzy logic-based control techniques have demonstrated potential in managing imprecise and uncertain data related to the operations of photovoltaic systems. Researchers have enhanced voltage stability and significantly reduced total harmonic distortion (THD) by using fuzzy logic controllers. Genetic algorithms (GAs) provide optimization tools to adjust harmonic mitigation techniques to different system dynamics and grid circumstances. According to research GAs [1] can be used to optimize the parameters of active power filters, which improves the performance of harmonic mitigation. Furthermore, hybrid strategies that combine fuzzy logic, ANNs, and GAs have shown promise in providing thorough harmonic mitigation for grid-integrated PV systems. All of this research demonstrates how soft computing methods can be used to reduce harmonics and enhance power quality in grid-connected photovoltaic systems. Through the utilization of ANNs, fuzzy logic, and genetic algorithms, which are known for their adaptability and computing capacity, researchers hope to address the issues related to harmonic distortion and make it easier for renewable energy sources to be seamlessly integrated into contemporary power networks. This study aims to design 5 an artificial neural network (ANN) vector control technique for a single-phase solar PV inverter to optimize power production while retaining system performance, safety, reliability, and controllability. 1 The efficacy of the ANN-based system is evaluated by simulating grid integration and power extraction in residential PV applications. The findings show that 5 ANN control outperforms conventional methods in both simulation and hardware implementation, especially in the face of noise, disturbance, distortion, and nonideal circumstances.[1]This work presents a fuzzy-based control technique that enables grid-connected solar PV systems to take part in frequency management without the need for energy storage. The system integrates hydro units, PV units, local loads, and non-reheat thermal units on IEEE 14-bus architecture. Primary frequency control is 1 provided by the fuzzy controller, which takes into account changes in system inertia and frequency deviation as inputs. Primary frequency responses are enhanced and the initial system frequency deviance is decreased using this strategy [2] To effectively extract and convert solar power, the paper suggests a fuzzy integrated MPPT controller. 1 This controller addresses problems such as tracking the maximum power point, PV mismatching, steady-state power variations, and increased total harmonic distortion. To lessen power swings and losses, the controller makes use of fuzzy sets, 49 rules, and seven linguistic variables. Comparisons are made between FLC-25 rules, perturb & observe-based MPPT controllers, and the suggested fuzzy-logic control (FLC)-49 rules base. A cascaded half-bridge multilevel inverter is treated with a particle swarm optimization (PSO)-based 13 selective harmonic elimination (SHE) technique to reduce switching losses and THD.[3]As a renewable energy source, photovoltaics (PV) is becoming more and more popular; yet, power quality disturbances can reduce PV's effectiveness. By controlling the DC-DC converter and making sure the maximum power point (MPP) is not exceeded, this research seeks to lessen these interruptions. Artificial neural networks (ANN) and cuckoo search (CS) are 14 two MPP tracking techniques that are created to maximize the PV system. To decrease injected 1 total harmonic distortion (THD) and improve power quality (PQ), the paper describes the design and implementation of a shunt active power filter (LCL) utilizing genetic algorithms and GRG. Simulation results demonstrate that this approach performs better than CS.[4]The goal of this research is to apply an adaptive approach using ANFIS to regulate variations in voltage and current in microgrid-generating sources within distribution networks. To control DC voltage power sources, a step-by-step Voltage Source Converter (VSC) controller was created. Each of the four microgrids that were created had a battery storage system, wind turbine, and photovoltaic plant. Both non-critical and critical loads were evaluated by the system. With the help of the suggested control system, which mitigates voltage and current fluctuations without the need for static synchronous compensators and power system stabilizers, the system voltage of 340 VAC is efficiently maintained.[5]This work uses an Adaptive Neuro Fuzzy Inference System (ANFIS) control technique to investigate power management in grid-connected microgrids. Four microgrids, each consisting of a wind turbine, two mass drive trains, a PMSM generator, a solar PV panel, and a battery energy storage system, are integrated into a 34-bus distribution network by the ANFIS-based power dispatch system. This study assesses how well a 34-bus radial distribution network can coordinate the operation of various grid-connected microgrids based on power sharing. The system assesses the best way to distribute power among several microgrids and is implemented in MATLAB/SIMULINK. Power dispatch in a 34-bus radial distribution network operating in the grid-connected and islanded mode of microgrids has proven successful when utilizing an ANFIS controller.[6]

III. Soft computing

Modern technology demands fresh ideas, which are put into practice using soft computing techniques. The foundation of conventional controllers is a set of mathematical equations that describe the steady and electric behavior of electrical systems. Comparing traditional controllers to soft computing techniques reveals how complicated they are. Modern soft computing technologies are expanding and performing well. Soft computing is the combination of approaches intended to model and enable solutions to real-world issues that cannot be quantitatively modeled or mathematically too difficult to model. Soft computing Consists are

- Fuzzy logic: to use fuzzy logic for knowledge representation Rule of If-Then.
- Neural Networks: to learn and adapt
- Genetic Algorithms: to compute evolution

Making smart machines is the primary goal of soft computing that can solve real-world issues that are either not modeled or are too complex to be formally modeled.

Approximation: The model features in this case are comparable to but not identical to the genuine ones.

Uncertainty: Here, we are unsure whether the model's features correspond to those of the Entity (belief).

Imprecision: 12 The model features (quantities) in this case are somewhat similar to the real ones but not the same.

IV. Soft computing Technique

Fuzzy system:

People are frequently interested in fuzzy logic controllers. Scientists in Japan once created 1 fuzzy logic controllers for everyday goods like washing machines and room heaters. Because of its broad use, it has been incorporated into many technical products.

Fuzzy number or fuzzy variable:

Take the following three sentences: zero, nearly zero, and near zero. Zero is exactly zero when given a truth value of 1. 3 If it is nearly 0, I can Consider that this is almost 0 and that the values between minus 1 and 1 are 0. Although I lack precision, that is how I often speak to perceive the outside world. When I say "near 0," perhaps the membership's bandwidth, which represents the truth value, is what I mean. As you can see, the bandwidth improves as you go closer to 0. This is how fuzzy numbers are thought of. Without getting into membership right now, a common misconception is that when I say "nearly 0," I allow 1 a small amount of bandwidth. My bandwidth still expands when I mention "near 0." Any data between minus 2 and 2 will still be regarded as being close to 0 in the case of minus 2 to 2. The confidence level of how close they are to 0 decreases as I move from 0 toward minus 2; for example, if 2 it is very close to 0, I am convinced. The amount of confidence decreases as I get further away from 0, but there is still a tolerance limit. So, when the value is zero, I am precise; when it is almost, I become less precise; and when it is three, I become much less precise. Fuzzy numbers are used to characterize the variables we meet in physical devices when we talk about fuzzy logic, and when a controller is created following this methodology, it is a fuzzy logic controller.

1 Fuzzy logic controller:

Because PID controllers are less effective than fuzzy logic controllers, they can operate in a wider variety of settings and produce disruptions and noises of many types than a PID can. To do the same purpose, a fuzzy controller 13 can be created for less money than a model-based controller or another type of controller. 1 In addition to using a user operator's scheme, fuzzy logic controllers can also be written in natural language, making them flexible to learn and adjust.

The fuzzy logic basic structure consists of four main components:

1. System with fuzzy interface

2. Information base

3. The logic of choice

4. Defuzzification,

4 Procedure to design FLC:

Step 1: Choosing the state variables and control variables.

Step 2: Choose an inference strategy

Step 3: Continue using the fuzzification technique

Step 4: Discretization of the state variable space's normal

Step 5: Dividing an unstable area

Step 6: Consistency of the fuzzy set shapes

Step 7: Establishing the fuzzy rule base

Step 8: Choose a defuzzification approach

Step 9: Test everything.

Step 10: Create the Lookup table

Some areas of fuzzy logic applications:

1. Automatically opening and closing dam gates for hydroelectric power plants

2. Flexible robot control

3. Camera aiming for sporting event telecasts

4. Effective and reliable engine management

5. Automobile cruise controls

6. Substituting a professional for stock exchange assessment duties

7. Optimised bus timetable design

8. System for earthquake early warning

9. Cancer is detected

10. Automatic vacuum cleaner motor control

Fuzzy controllers in consumer applications:

1. Goods for consumers

TVs and VCRs; vacuum cleaners; rice cookers; washing machines; microwave ovens; thermal carpets; word translators

2. Systems

Automobiles; Elevators; Trains; Cranes; Traffic control

3. Software

Medical evaluation, Securities, Data compression

[1] Fuzzy logic controller:

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The fuzzy logic basic structure consists of four main components:

1. System with fuzzy interface
2. Information base
3. The logic of choice
4. Defuzzification,

V. Artificial Neural Network

Hebb's training technique, which showed how a system of neurons may show knowledge behavior, served as the inspiration for ANN. Artificial Neural Networks are primarily categorized by their topology architecture and learning regime. Multi-layer feed-forward networks are used in the majority of ANN applications in power systems.

Advantages:

It is quick, capable of learning, adapts to the data, is tough, and is suitable for non-linear modeling. These benefits point to the application of Artificial Neural Networks for monitoring and managing voltage safety. Even while neural network training often requires expensive computer resources, once the network has been trained, evaluating voltage stability only requires a small amount of time.

Application:

Planning, including capacitor placement and voltage control, long-term load prediction, Economic dispatch/unit commitment, transient stability, fault diagnosis, load flow, and static and dynamic security evaluation are all part of the operation.(Power System Stabilizer) Analysis.

Features of Artificial Neural Network (ANN) models:

1. Distributed parallel information processing
2. Strong connectedness between fundamental units
3. Experience-based adjustments can be made to connections.
4. The process of learning is ongoing and unsupervised.
5. Draws on local knowledge to inform learning

6. Performance suffers when there are fewer units

VI. Genetic algorithm

The GA controlling approach [11] is a method for explaining optimization issues that are driven and undriven and rely on normal selection, the mechanism that drives biological selection. An ongoing population of individual outcomes is revised by the GA. The GA selects people from the current population to be parents at each stage of the process and uses them to bear the future generation's offspring. Overly optimistic generations [1] result in the population "evolving" before a regular solution. We can utilize the GA to address a variety of optimization issues, such as those where the objective method of the function is interrupted, non-differentiable, difficult, or extremely nonlinear, which are not well suited for conventional optimization techniques. The GA can detect issues with various integer GA programs, including if some elements are required to have integer values.

The GA utilizes three main kinds of rules at each process step [1] to create the future generation of the present population:

1. Decision-making processes choose the people, known as parents, who will make up the population of the following generation.

2. Crossover determines how compound two parents produce offspring for the following generation.

3. To create children, mutation controls randomly alter each parent.

Advantages of GA:

1. It lays no [2] restrictions on the objective function, such as differentiability and convexity, and only requires basic knowledge of the objective function.

2. The technique does not use a single solution but instead, [15] a set of solutions from one generation to the after that, which reduces the likelihood that it would reach local minima.

3. Since the initial explanation is produced at random based on the likelihood of genetic operators like change and intersect, the GA's search approach is unaffected by them.

Steps involved in the genetic algorithm:

Step1: Random initialization of population

Step2: assessing each person's fitness within the population

Step3: New population generation

Step 4: Evaluate population, GOTO Step 2 If the stop criteria are met, halt the search for the ideal solution.

Genetic algorithm applications:

1. Dynamic Expecting Routing in Circuit and Switched Telecommunications Networks,

2. Genetic Algorithms in Parametric Aircraft Design

3. Robot trajectory generations with GA

4. Models of Global Security, Nonlinear Dynamical Systems, and GA

VII. Conclusion

The application of soft computing techniques such as artificial neural networks, fuzzy logic, and genetic algorithms holds significant promise for enhancing the power quality of grid-integrated photovoltaic systems. These techniques offer adaptable and effective solutions for mitigating harmonic distortion, thereby improving system performance and ensuring seamless integration with modern power grids. By leveraging the computational power of soft computing, researchers aim to address the challenges associated with harmonic distortion, ultimately advancing the sustainable integration of renewable energy sources into the energy infrastructure.

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