ANFIS-Based Bi-directional Grid Connected EV Charging Station With Battery Storage System: - A Review

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Abstract - *The need for contemporary transportation infrastructure is growing along with concerns about dangerous climatic changes and global warming. To resolve this issue, countries are promoting the use of Electric Vehicles (EVs). However, dependency on fossil fuel-based infrastructure for charging EVs is not efficient. An EV charging station powered by renewable energy has significant potential for EV charging. A solar-powered charging station and a BESS (Battery Energy Storage System) are essential in the present situation. It is also recommended to provide additional grid support to ensure uninterrupted power supply to the charging station without overloading the grid. ANFIS-based MPPT tracks the maximum power from the solar PV array. Generate the power and charge the EV battery and Stationary battery storage system from the PV source and also transfer power to the grid. When the PV array does not generate power and no power in the stationary battery storage system then the Grid charges the stationary battery storage system and the EV battery. The findings of the present research can also help to increase power efficiency and the power factor should be maintained.*

Key Words: PV source, BES Grid, EV Station, Bi-directional converter, ANFIS, PID,

1. Literature Review

1.1 Solar PV Power Generation

Islam et al (2022) provide a comprehensive review of recent advancements in solar PV technologies and applications. The study covers various aspects, including solar cell technologies, module design, integration techniques, and emerging applications, highlighting the rapid progress and potential future trends in the field. [5]

Colasante et al (2022) explore the role of solar PV in global energy transition scenarios. The study emphasizes the significant potential of solar PV to drive de-carbonization efforts and highlights the importance of policy frameworks and market incentives to facilitate the widespread adoption of solar PV technologies. [4]

K. M. Tan et al (2021) described a review on energy storage integration in solar PV systems. The study discusses the challenges and opportunities associated with incorporating energy storage technologies, such as batteries and pumped hydro storage, into solar PV installations, emphasizing the role of storage in enhancing grid stability and maximizing renewable energy utilization. [9]

Nwaigue et al (2019) conduct a review on the smart grid integration of solar PV systems. The study examines the challenges and potential solutions for integrating solar PV into existing power grids, focusing on aspects like grid stability, power quality, and control strategies, highlighting the need for advanced grid management techniques to optimize solar PV integration [16]

Raugei et al (2017) investigate the EROI of photovoltaic as compared to fossil fuel life cycles. The study presents a comprehensive methodology for assessing EROI and provides insightful comparisons, emphasizing the favourable energy payback characteristics of solar PV systems. [21]

1.2 ANFIS-Based MPPT Techniques

Kumar et al (2021) described the ANFIS-based MPPT technique for standalone solar PV systems. The proposed method utilizes ANFIS to estimate the optimal operating point, achieving efficient tracking performance and enhancing the energy yield. [10]

Bendary et al (2021) described the ANFIS (Adaptive-Network-Based Fuzzy Inference System) used for MPPT in photovoltaic systems. The proposed ANFIS-based MPPT controller adapts to changing environmental conditions, ensuring accurate tracking and improving the overall system efficiency. [11]

G. Liu, et al (2020) introduced a comparative study of different ANFIS-based MPPT algorithms for standalone solar PV systems. The study evaluates the algorithms' tracking accuracy, convergence speed, and stability, providing valuable insights for selecting an optimal ANFIS-based MPPT approach. [14]

U. Yilmaz et al (2019) A MPPT (“Maximum Power Point Tracking”) method was developed. It consists of two main components: A FLC ("Fuzzy Logic Controller") block is utilized to modify the duty cycle of the MOSFET (PWM applied switch) in the DC to DC converter. Additionally, the MPPT reference voltage point calculation block is adapted. The effectiveness of the proposed technique was assessed using the MATLAB/Simulink program by comparing its conductance to that of the conventional P&O ("Perturb & Observe") and Incremental Conductance (Inc. Cond.) methods.[17]

Khan, I. U. et al (2019) proposed a comparative analysis of various MPPT techniques, including ANFIS-based approaches, for grid-connected solar PV systems. The results demonstrate that the ANFIS-based MPPT method achieves superior performance in terms of tracking efficiency and energy harvesting. [18]

1.3 Solar PV Integration with EV Charging Stations

Alrubaie et al (2023) presented the issues and recommendations for future grid integration and EV charging infrastructure expansion, which is assessed and summarized. It indicated that PV-grid charging can make a profit. However, the power system might not be economical because of the PV and batteries' limited capacity. Furthermore, PV is likely to be unable to provide enough electricity to meet customer demand due to its intermittent nature [2]

Ahmad et al (2021) presented a technique that uses a feed-forward NN to determine the predicted solar power from the connected PV plant and a stochastic technique to estimate the projected EV load demand at the charging stations. Moreover, an investigation is conducted with interesting results on the effects of EV load demand on the distribution network with respect to average voltage deviation index, power loss, voltage stability index, and per unit voltage profile. [13]

Singh et al (2021) presented the design and optimization of a solar PV charging station for EVs. It discusses various aspects, including PV system sizing, energy storage, and charging infrastructure layout. The research provides insights into maximizing the utilization of solar energy for EV charging. [12]

Dai et al (2019) introduced an optimization system to size PV and BESS and assess the charging and/or discharging pattern of BESS for grid-connected photovoltaic/battery energy storage/EV charging stations (PBES) [19]

1.4 Artificial Neural Network (ANN) for Solar PV

Jlidi et al (2023) Focussed on short-term solar power prediction, this review examines the application of ANNs in forecasting solar PV output. It discusses different ANN architectures, input parameters, and training algorithms used for accurate and reliable predictions. The study highlights the advantages and limitations of ANN-based solar power forecasting models. [1]

Rohit et al (2022) provided a comprehensive review of ANN applications and control in microgrid energy management systems, which includes solar PV integration. It explores how ANNs can be used for load forecasting, power flow optimization, and grid interaction control. The research offers insights into the integration of ANNs in managing solar PV systems within microgrids. [8]

Malik et al (2022) compared different ANN models for short-term solar power prediction. It evaluates the performance of various architectures, training algorithms, and input feature combinations. The study presents valuable insights into the selection and optimization of ANN models for accurate solar PV output forecasting. [6]

W. Khan et al (2022) focussed on comparative analysis and explored different ANN models for photovoltaic power prediction. It evaluates the performance of different architectures, activation functions, and training algorithms. The study emphasizes the benefits and drawbacks of each model and guides the selection of the most suitable ANN approach for solar PV power prediction. [7]

Baojie et al (2020) introduced various applications of ANNs in photovoltaic systems. It covers topics such as solar irradiance prediction, power output forecasting, fault diagnosis, and performance optimization. The study provides insights into the potential of ANNs in improving the efficiency and reliability of solar PV installations. [15]

1.5 Battery Storage Systems: -

B. Scrosati et al (2010) proposed that Lithium-ion batteries are commonly utilized in a variety of applications owing to their long cycle life, high energy density, as well as fast charging capabilities (Nitta et al., 2015). Demonstrated significant improvements in the performance as well as safety of lithium-ion batteries by the expansion of new materials and innovative cell designs. [22]

H. Wang et al (2023) described on Flow of batteries, such as vanadium redox flow batteries (VRFBs), offer scalable and long-duration energy storage solutions (Skyllas-Kazacos et al., 2011). Highlighted the advancements in VRFB technology, including the use of novel electrode materials and the optimization of electrolyte compositions for improved efficiency. [3]

Krewer et al (2018) introduced that BMS plays a crucial role in monitoring and controlling battery performance, safety, and longevity. Presented advancements in BMS algorithms and techniques for SOC ("State-Of-Charge") estimation, SOH ("State-Of-Health") prediction, and thermal management to enhance battery performance and extend its lifespan. [20]

2. Proposed Methodology

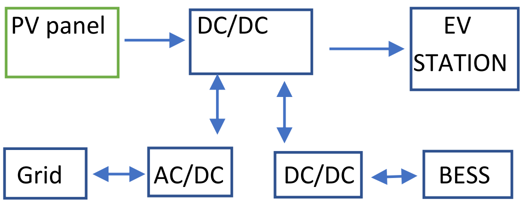

Fig.:- ANFIS Bi-directional Grid Connected EV Charging Station with Battery Storage System

The first part is the generation parts, in which the PV array is Generate the power by the use of solar irradiation and temperature. The PV Arrey uses Maximum power point tracking (MPPT) for maimum generation of power. The power generated by PV system is in the form of DC which is further covterted in AC by inverter. Supply power from PV source is fed to EV charging station with the DC link voltage.

Stationary battery storage system is connected with PV source and EV charging Station by the use of DC- DC bidirectional converter. When extra power is generated by PV array or No vehical is connected to EV station it will be stored in Stationary battery storage system. Which will provide back source to EV station when PV arrey is OFF.

PV source is directly connected with the EV charging station as well as the stationary battery. Grid connected to the EV Charging Station with the DC link.

Grid is connected to PV source and EV charging system and as well as the Stationary battery storage system. To supply the power from PV to Grid and grid to EV.

Adaptive nuero fuzzy interface system is work same as Fuzzy interface system. ANFIS is used to create a model of a solar PV system that is identical to the original in this MPPT structure. Under diverse irradiance and temperature conditions, ANFIS is trained with two inputs (irradiance and temperature) and a single output(voltage).

A PWM (Pulse Width Modulation) generator for solar panels is a device that helps regulate the amount of energy being generated by the solar panels. The PWM generator works by controlling the amount of energy that is being transferred from the solar panels to the battery or grid, ensuring efficiency and safety. [4]

Buck-boost converter is a type of DC-DC converter that operates by converting DC voltage from a source at one level to a different level. It is a switch-mode power supply that can step up or step-down voltage levels depending on the input and output configurations.

PLL (Phase-Locked Loop) is commonly used in grid-connected photovoltaic (PV) power systems to synchronize the PV system's output with the grid frequency and phase In a grid-connected PV system, the PV panels generate DC power, which is converted into AC power using an inverter. The AC power needs to be synchronized with the grid frequency and phase to be able to be fed into the grid The PLL system measures the phase and frequency of the grid voltage and adjusts the inverter's frequency and phase to match the grid. The PLL system uses a feedback loop to control the inverter's frequency and phase.

A PI controller is a type of feedback controller commonly used in engineering applications to regulate a system's behaviour. In the context of a solar PV EV charging station, a PI controller can be used to adjust the charging rate of an electric vehicle's battery based on the amount of available solar energy.

An LCL filter is a type of filter circuit that is often used in power electronics applications to reduce harmonic distortion in the output of an inverter. The filter consists of an inductor (L), capacitor (C), and inductor (L) connected in series between the output of the inverter and the load. The LCL filter is designed to reduce the high-frequency components in the output voltage waveform of the inverter.

In the Proposed method we use combinations of ANFIS-based bidirectional converters. With the help of converters, we can transfer power according to need. The proposed model works in the following mode: -

- **1st Mode:**

EV battery charging with PV array alone. In the present mode, the temperature remains constant, the irradiance of the PV panel is adjusted, and the ANFIS voltage-controlled approach is applied to extract the power from the PV array.

- **2nd Mode:**

Solar energy is only utilized to charge EV batteries and BESS when the BESS is linked to a DC bus. PV panel operation at MPPT using ANFIS.

- **3rd Mode:**

EV batteries are charged with a combination of BESS and solar electricity under varying irradiance conditions. The maximum power that may be drawn from the PV array is ensured by ANFIS.

- **4th Mode:**

When the PV array is not producing solar radiation at night, the BESS and AC grid are utilized to charge the EV battery. The AC grid's power flow is managed by a functional fitting neural network.

- **5th Mode:**

The PV array's temperature and irradiance are adjusted. When an AC grid, BESS, and solar PV array are connected, excess electricity is supplied into the AC grid and used to charge EV batteries.

3. CONCLUSIONS

An ANFIS Bi-directional Grid Connected EV Charging station with a Battery Storage System is proposed. The proposed method provides an elegant way of combining Solar PV, GRID, as well as Battery energy systems for charging EVs in EV stations. This will reduce carbon emission also maximize the use of renewable energy. Which will lead to reduced global warming. Also, minimizes the dependency on conventional resources and the grid to charge the electric vehicle.

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