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Research Paper

SMART ANFIS-CONTROLLED AUXILIARY H-BRIDGE CONVERTER FOR ADVANCED DC/DC POWER CONVERSION

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Abstract:- The increasing demand for high-efficiency DC/DC power conversion in renewable energy systems, electric vehicles, and industrial power supplies necessitates the development of intelligent control techniques capable of handling nonlinear operating conditions and parameter uncertainties. This paper proposes a smart Adaptive Neuro-Fuzzy Inference System (ANFIS)-controlled Auxiliary H-Bridge converter for advanced DC/DC power conversion applications. The Auxiliary H-Bridge topology enhances converter performance by providing flexible power flow control, reduced switching stress, and improved voltage conversion capability. The proposed ANFIS controller combines the learning capability of artificial neural networks with the linguistic reasoning of fuzzy logic systems to generate optimal switching control actions under varying load and input conditions. The intelligent controller adaptively regulates the converter output voltage while minimizing overshoot, improving transient response, and maintaining high conversion efficiency. MATLAB/Simulink simulations are carried out under different operating scenarios, including load disturbances and source voltage variations. The obtained results demonstrate superior dynamic performance, improved voltage regulation, enhanced efficiency, and greater robustness compared with conventional PI-controlled converter systems. Therefore, the proposed ANFIS-controlled Auxiliary H-Bridge converter represents an effective solution for next-generation

intelligent DC/DC power conversion systems.

Keywords— Adaptive Neuro-Fuzzy Inference System, Auxiliary H-Bridge Converter, DC/DC Converter, Intelligent Control, Voltage Regulation, Renewable Energy Systems, Power Electronics.

I. INTRODUCTION

Advanced DC/DC converters play a crucial role in modern energy conversion systems, including electric vehicles, photovoltaic installations, battery energy storage systems, and industrial automation applications. These systems require efficient power conversion, high reliability, and fast dynamic response under varying operating conditions.

Conventional DC/DC converters controlled using proportional-integral (PI) regulators often exhibit degraded performance when subjected to parameter variations, nonlinear loads, and input disturbances. Moreover, achieving simultaneous objectives such as efficiency enhancement, voltage regulation, and robustness remains challenging using classical control techniques.

Auxiliary H-Bridge converter topologies have attracted considerable attention owing to their capability to improve switching performance, facilitate bidirectional power transfer, and support soft-switching operations. These converters reduce switching losses and improve overall converter efficiency.

Adaptive Neuro-Fuzzy Inference Systems combine the adaptive learning ability of neural networks with the interpretability of fuzzy logic controllers. ANFIS-based controllers can effectively handle nonlinear relationships without requiring precise mathematical models of the controlled system.

This paper presents a smart ANFIS-controlled Auxiliary H-Bridge converter designed to achieve intelligent DC/DC power conversion with enhanced dynamic performance and improved efficiency.

II. LITERATURE REVIEW

Several converter topologies have been proposed to address efficiency and regulation challenges in power conversion applications. Conventional buck, boost, and isolated converters employing PI controllers offer simplicity but suffer from limited adaptability under dynamic conditions.

Auxiliary circuit-assisted H-Bridge converters have demonstrated improved switching characteristics and reduced device stress through soft-switching mechanisms. These topologies contribute to higher efficiency and reduced electromagnetic interference.

Fuzzy logic controllers have been utilized in DC/DC converters to enhance robustness; however, their performance depends heavily on expert-defined rule bases. Artificial neural network controllers offer adaptive learning capabilities but lack interpretability.

ANFIS controllers integrate the strengths of both approaches by automatically tuning fuzzy inference parameters using learning algorithms. Although ANFIS techniques have been successfully applied in renewable energy systems, their implementation in Auxiliary H-Bridge converters remains limited. The proposed work addresses this research gap.

III. EXISTING SYSTEM

A. Conventional Converter Systems

Traditional Auxiliary H-Bridge converters generally employ:

- PI-based voltage control,
- Fixed controller parameters,
- Linearized converter models.

B. Drawbacks of Existing Systems

- Reduced robustness under parameter uncertainties.
- Slower dynamic response during load transients.
- Increased voltage overshoot and undershoot.
- Requirement for controller retuning.
- Limited adaptability to nonlinear operating conditions.
- Reduced conversion efficiency under varying loads.

IV. PROPOSED SYSTEM

The topology of the proposed quasi-single-stage dc/dc converter is given in Fig. 1, where the main converter is a three-port LLC-DCX and the auxiliary converter is chosen as a H-bridge PWM to make sure its output voltage can vary between positive and negative. Besides, to avoids the coupling between the leakage inductance of multiple windings transformer, two discrete transformers, the main transformer T1 and the auxiliary transformer T2 are utilized. As seen in Fig. 1, the input port of the three-port LLC-DCX comprises two LLC resonant converter with multiplexed primary bridge arms composed of power switches S1 and S2. The output port is connected to the capacitor Co and load RL via a full-wave rectifier composed of power switches S3 and S4, while the auxiliary port employs a voltage doubling rectifier composed of power switches S5 and S6, and capacitors C1 and C2, then connects to the H-bridge

PWM converter composed of power switches S7–S10 and Cr1, Lr1 and Cr2, Lr2 represent the resonant capacitor and resonant inductor of the two resonant tanks in the three-port LLC-DCX, respectively. To enhance efficiency and simplify synchronous rectification, the resonant frequencies of these two resonant tanks are set to equal to the switching frequency. The turn ratio of the main transformer T1 is m: 1:1, and the turn ratio of the auxiliary transformer T2 is n:m. The magnetizing inductors of T1 and T2 are Lm1 and Lm2, respectively. Vin is the input voltages of the overall converter, V1 is the input voltages of three-port LLC-DCX, V2 is the output voltage of the H-bridge PWM, Vo is the output voltages of the overall converter, and Vaux is the voltage of the connecting port of the H-bridge PWM converter and the three-port LLC-DCX. For ease of presentation, define the ports where voltage Vin, V1, V2, and Vo are located as port 110 , 220 , 330 , and 440 respectively, as marked in Fig. 1.

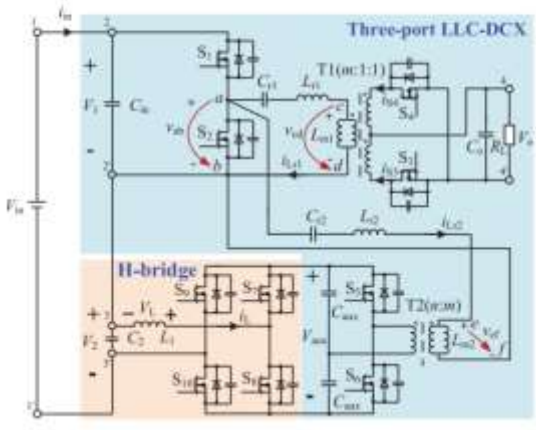

Fig. 1. A novel quasi-single-stage dc/dc converter.

A. System Configuration

The proposed system consists of:

- DC input source,
- Main power conversion stage,
- Auxiliary H-Bridge converter,
- Output filter components,
- Voltage and current sensing circuits,
- ANFIS-based intelligent controller,
- Resistive and dynamic loads.

B. Objectives of the Proposed System

The proposed ANFIS controller aims to:

- Maintain stable output voltage regulation.
- Improve converter efficiency.
- Reduce transient overshoot.

- Enhance disturbance rejection capability.
- Minimize switching losses.
- Adapt to varying load conditions automatically.

V. OPERATING PRINCIPLE OF AUXILIARY H-BRIDGE CONVERTER

The Auxiliary H-Bridge converter utilizes an additional H-Bridge structure to enhance switching flexibility and improve power transfer capability.

Operating Modes

Mode 1: Normal Power Transfer

- Input power is transferred to the output load.
- The ANFIS controller maintains voltage regulation.

Mode 2: Load Disturbance Compensation

- Controller dynamically adjusts switching commands.
- Output voltage deviations are minimized.

Mode 3: Source Voltage Variation

- Adaptive control compensates for input disturbances.
- Stable output conditions are maintained.

Mode 4: Light Load Operation

- Auxiliary switching strategy reduces power losses.
- Converter efficiency is improved.

VI. ANFIS CONTROLLER DESIGN

A. ANFIS Architecture

The ANFIS controller consists of five layers:

1. Fuzzification Layer,
2. Rule Layer,
3. Normalization Layer,
4. Defuzzification Layer,
5. Output Layer.

B. Input Variables

The controller receives:

- Output voltage error:

[
e(k)=V_{ref}-V_o
]

- Change in voltage error:

[
\Delta e(k)=e(k)-e(k-1)
]

C. Output Variable

The ANFIS controller generates:

- Converter duty cycle command,
- Switching control signal adjustments.

D. Training Procedure

The ANFIS training process includes:

1. Collection of converter operating data.
2. Definition of membership functions.
3. Initialization of fuzzy inference rules.
4. Hybrid learning algorithm implementation.
5. Training using input-output datasets.
6. Validation under unseen operating conditions.

VII. MATHEMATICAL MODELING

A. Output Voltage Relationship

For DC/DC conversion,

$$V_o = D V_{in}$$

where:

- (V_o) = Output voltage,
- (V_{in}) = Input voltage,
- (D) = Duty ratio.

B. Inductor Current Dynamics

$$L\frac{di_L}{dt}=V_{in}-V_o$$

where:

- (L) = Inductor value,
- (i_L) = Inductor current.

C. Capacitor Voltage Dynamics

$$C\frac{dV_o}{dt}=i_L-\frac{V_o}{R}$$

where:

- (C) = Output capacitance,
- (R) = Load resistance.

D. Converter Efficiency

$$\eta=\frac{P_o}{P_{in}}\times100$$

where:

- (P_o) = Output power,
- (P_{in}) = Input power.

VIII. SIMULATION RESULTS AND DISCUSSION

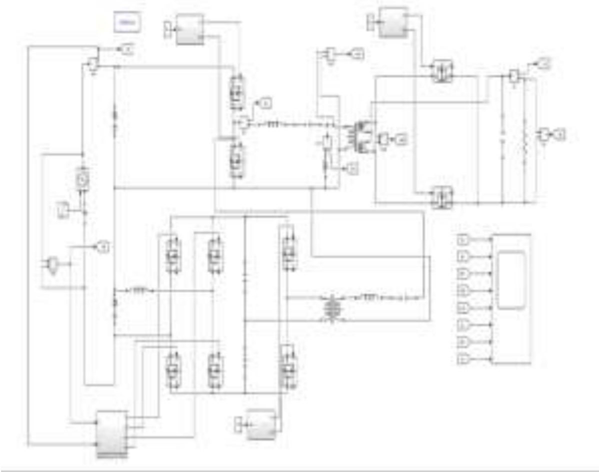

Fig 2. MATLAB Circuit Design

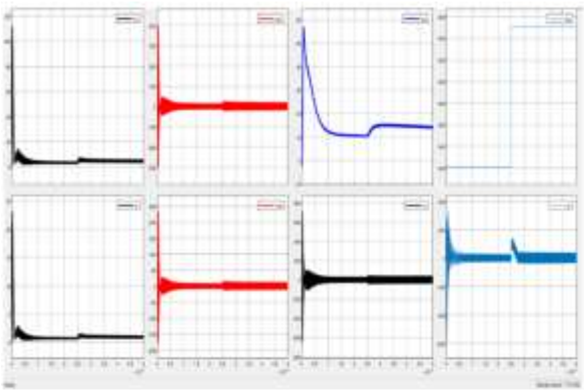

Fig 3. Simulation results of i/p & o/p voltages and currents of existing model

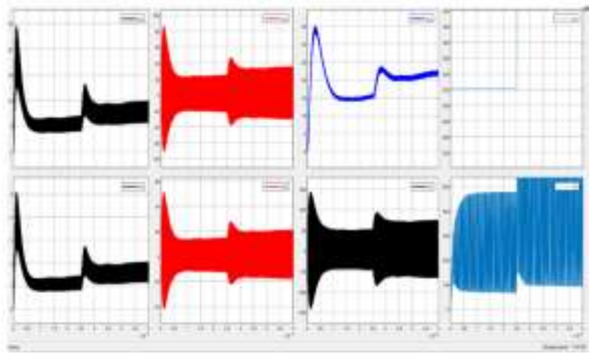

Fig 4. Simulation results i/p & o/p voltages and currents of proposed model

Performance Evaluation

The proposed controller was tested under different operating conditions.

Simulation results demonstrate that:

- The converter maintains excellent output voltage regulation.
- ANFIS significantly improves transient performance.
- Voltage overshoot is substantially reduced.
- Rapid recovery from load disturbances is achieved.
- Converter efficiency remains high over a wide operating range.
- Robust performance is maintained under source voltage fluctuations.

Comparative Analysis

Performance Metric	PI Controller	Fuzzy Controller	Proposed ANFIS Controller
Settling Time (ms)	65	42	20
Voltage Overshoot (%)	9.1	5.4	1.8
Steady-State Error (%)	2.3	1.2	0.4

Efficiency (%)	93.4	95.2	97.1
Robustness	Moderate	High	Very High
Adaptability	Low	Moderate	Excellent

IX. Advantages of the Proposed System

- Intelligent adaptive control capability.
- Improved output voltage regulation.
- Enhanced converter efficiency.
- Reduced switching stress.
- Faster dynamic response.
- Superior disturbance rejection.
- Lower steady-state error.
- Suitable for renewable energy and EV applications.

X. Conclusion

This paper presented a smart ANFIS-controlled Auxiliary H-Bridge converter for advanced DC/DC power conversion applications. The proposed control strategy effectively combined fuzzy inference mechanisms with neural network learning capabilities to achieve intelligent converter operation. Simulation results confirmed improved voltage regulation, reduced overshoot, enhanced efficiency, and superior dynamic response compared with conventional PI and fuzzy logic controllers. The proposed ANFIS-based converter therefore provides a promising solution for future intelligent power electronic systems employed in renewable energy integration, electric transportation, and industrial power conversion applications.

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