Study on the optimized control strategy of the DAB converter

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Abstract: Due to the rapid development of DC power generation and transmission technology, it has become the central link of high voltage AC transmission and low voltage DC distribution network, and the medium and low voltage DC distribution network has attracted more attention. In the medium and low voltage DC distribution network, the high-frequency isolation bidirectional DCDC-driven converter is required as an interconnection equipment for electrical isolation, current conversion and bidirectional power flow. To reduce the voltage stress of the switching element of the dual active bridge (DAB) autoconverter used in the medium voltage environment, the three-level topology is incorporated into the autoconverter of the audio broadcast. The three-input-output level (3L) DAB converter has the advantages of both input-output level automatic converter and DAB converter, which is more convenient to operate and has great application and development prospects. For the 3L-DAB converter and its optimal management, taking the double-free-phase-shift controller as an example, it first constructs the segmented time-domain map mode of the automatic converter, and analyzes its operation characteristics, which provides a basis for the subsequent research. The power switching transistors of the two-channel free phase-shift timing converter meet the soft switching requirements, and we deduce the influence of the nonlinear influence on the soft switching range. Then, the reliability optimization strategy is given in view of the non-matching conditions, and then the equivalent conditions of the two optimization methods are derived. Finally, we analyze that the segmented time domain mapping method is not suitable for the model changes, construct the multi-degree of freedom universal phase shift controller mode, and derive the fundamental wave optimization game.

Keywords: DAB Converter; Soft Switch Characteristics; Optimal Control

Foreword

At present, the mainstream DAB converter modulation mode is mainly divided into the following two kinds: (1) duty cycle control: using the method of changing the duty cycle to change the size and direction of the transmission power, mainly suitable for low power occasions.(2) Phase shift control: the energy flow of the converter is controlled by controlling the phase of the switch tube drive signal, which has the advantages of fast response and high efficiency. The phase shift control methods mainly include SPS control, DPS control and EPS control. In this paper, we will explain the basic topology structure of DAB converter, study the basic operation mechanism and functional state of DAB converter under SPS control, DPS control and EPS control system, deduce the basic laws of primary and secondary voltage and inductor current, and establish the mathematical model.

1. The DAB converter topology

The topology of DAB converter is shown in Figure 1, where the whole input side bridge is from switch tube to and reverse diode, forming the full output side bridge from to sum to; L is the original side inductor:$Q_1Q_4D_1D_4Q_5Q_8D_5D_8$.

$V_{in1}V_{00}$, Input and output voltage of the converter:, the capacitance on both sides of the converter: inductance current: output current: the midpoint voltage of the input bridge, the midpoint voltage of the output bridge: the converter variable ratio is n: I, the working frequency is f, and the defined voltage transmission ratio is K = /.$C_1C_0i_Li_0U_{h1}U_{h2}V_{in1}V_{co}$.

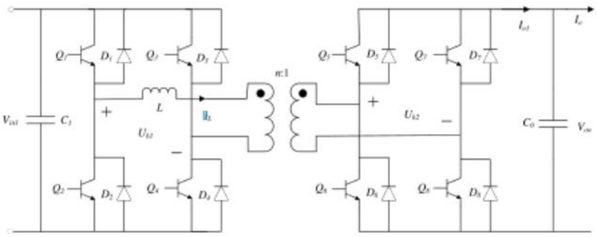

Figure 1 The DAB converter topology

Phase shift control is to control the energy flow of the converter by controlling the phase of the drive signal of the switch tube. Forward transmission when the phase shift angle between the input and output bridges is greater than 0°; reverse transmission when the phase shift angle is less than 0°. Considering the similar principle of power transmission, in order to simplify the analysis process, the forward transmission is used as an example to analyze the working principle of the DAB converter. The operating state of the converter is under the following assumptions: (1) the converter is in the steady state; (2) it only considers the voltage transmission ratio K 1, and the case of K <1 is similar to the analysis method.

2. Current stress optimization based on an improved differential evolution particle swarm algorithm

When the input and output current of the DAB converter does not match, there will be problems such as current stress, increased return power, and even device damage, so its control needs to be optimized. Since the single-phase shift control has only one phase shift to adjust, it is difficult to optimize the control. Although both the DPS control and the EPS controls have multiple group phase shifts, it still needs to choose the optimal phase shift to optimize the current stress. To solve the above problems, this chapter analyzes the transmission power and current stress of DAB converter under SPS control, DPS control and EPS control, establishes corresponding models and compares them. Based on the analysis of differential evolution algorithm and particle swarm optimization algorithm, an improved algorithm is proposed, and then its performance is verified. Finally, we propose a current stress optimization control strategy based on the improved differential evolution particle swarm algorithm, which realizes the optimal control of the current stress and gives a block diagram of the optimal control strategy.

2.1 Transmission power characteristics under single-shift phase control

When the DAB converter is under SPS control, the inductance current in one switching cycle is:

$$(t)=\begin{cases} i_L(t_0)+\dfrac{V_{in1}+nV_{on}}{L}(t-t_0)t\in(t_0,\ t_2) \\ i_L(t_2)+\dfrac{V_{in1}+nV_{on}}{L}(t-t_2)t\in(t_2,\ t_3) \\ i_L(t_3)+\dfrac{V_{in1}+nV_{on}}{L}(t-t_3)t\in(t_3,\ t_5) \\ i_L(t_5)+\dfrac{V_{in1}+nV_{on}}{L}(t-t_5)t\in(t_5,\ t_6) \end{cases}$$

2.2 Improved differential evolution particle swarm algorithm

DE algorithm and PSO algorithm are intelligent search algorithms, which produce different individuals in their own advantages and disadvantages. Since the DE algorithm captures the intermediate individual group by reconstructing the current individual differences and comparing the fitness values of individuals to select individuals, the search results of the DE algorithm are stable. However, because the greedy method is used in the selection process, the adaptable individuals can be retained and the complexity of the intermediate population is maintained iteratively, so the DE algorithm highly relies on the selection of parameters and has low convergence efficiency in the later stage of individual evolution. In the PSO algorithm, the new particles come from the best location of the particle itself and the best position of the population. The algorithm has few parameters and simple structure, but it is easy to find the global optimal solution later in the algorithm. In order to overcome the disadvantages of the differential evolution algorithm and the particle swarm algorithm, the collaborative hybrid algorithm based on the differential evolution algorithm and the particle swarm algorithm is improved. That is, different evolutionary strategies are used to screen particles to ensure that the new generation population has higher adaptation values and better particles. The traditional DEPSO algorithm uses the total population for variation operation, and the algorithm will fall into the local optimum later. Therefore, this paper, the IDEPSO algorithm divides the population into two subpopulations 1 and 2 subpopulations as and, ensuring that N= +, = (t / Max) * N,$N_1N_2N_1N_2N_2$

Where t is the current number of iterations and Maxit is the maximum number of iterations, the DE / land / 1 and DE / currentto-best / 1 are used. The two variation strategies are good at global search and local search respectively. The DE / rank / 1 mutation strategy is used at the initial stage of the algorithm, and the DE / currentto-bes / 1 mutation strategy is used in the later stage of the algorithm to improve the search accuracy.

2.3 Direct power control strategy

Direct power management strategy originates from the direct torque control system in the motor control system. Compared with the traditional voltage closed-loop control, it has better dynamic performance and versatility. Therefore, this control strategy is widely used in DC / DC converters, and has achieved significant results in energy storage system, DC micro-grid and other fields. According to the mathematical model of the DAB converter, the relationship between the input efficiency and the phase shift comparison is derived. According to the input efficiency requirements of each DAB converter, the phase shift comparison is sent to the corresponding converter to realize the single-phase shift management, while the direct power management technology can realize the corresponding efficiency management of various functions in the modular DAB converter. It can effectively overcome the problem of uneven energy transfer of DAB converter with different functional parameters under the same duty cycle control strategy, and also has the function of rapid response to the mutation of the system load. Moreover, this strategy design has no inductance, switching time and other parameters, the design is relatively simple and portable, easy to facilitate the popularization and application of technology. However, the management efficiency of the direct power management technology is not ideal in the load mutation, and its dynamic response speed is relatively slow in the case of the load mutation, which is not conducive to the modularity.

3. Based on the voltage-feedforward control strategy

Based on the voltage feedforward control strategy, in order to ensure the same input and output voltage, the average difference between the maximum input and output voltage and the average input and output voltage of each unit is controlled, and the voltage compensation is made in accordance with a certain proportion in each module, and then the closed-loop control is conducted to realize the power balance of the modular DAB converter. The control strategy mainly adopts three current closed-loop control modes, namely, output current control outer loop, output current feedback control inner loop and input current balance control loop. The output current control outer loop is mainly responsible for monitoring the current closed loop of each automatic converter. The output current feedback control inner loop is to improve the dynamic performance of the converter, and the input voltage balance control link is to balance the input voltage. The power balance of the modular DAB converter can be achieved through a three-ring structure. In this strategy, the input voltage of each module is consistent, and the output current is evenly divided to achieve the power balance. However, this strategy requires real-time sampling and calculation of the circuit data of each module to realize the control strategy, which needs to sample the most data, and the control system is relatively complex.

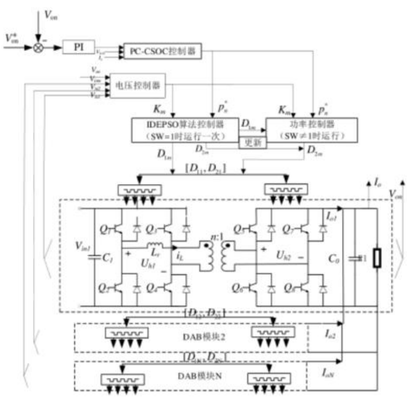

Figure 2 Block diagram of PC-CSOC control

3.1 System structure of the semi-physical simulation platform

The modular DAB converter system consists of multiple single DAB converters in series and in parallel, with many components and complex control. When the actual hardware platform verifies the correctness of the PC-CSOC control strategy, the peak of the current and voltage can easily lead to the switch pipe breakdown, cause circuit damage, increase the experimental cost, and the experimental process is complicated. Moreover, during the experiment, if the control strategy is not reasonable and the circuit hardware parameters fail, the experiment will affect the experimental results. Therefore, when the experiment is wrong, it is probably impossible to accurately judge the cause, resulting in the failure of the experiment. Hardware in the ring simulation platform system adopts the physical controller, and the control object adopts the model. This method can eliminate the influence of circuit hardware parameter design on the control strategy: because the controller is physical, it can well reflect the correctness of the proposed control strategy, which plays an important role in the construction of the subsequent physical platform. This paper will provide a 0.5 physical simulation system of the DSP28335-based modular DAB automatic conversion system to simulate the PC-CSOC management strategy.

3.2 Serial port communication design

The following three serial port communication schemes are usually used between the controller and the control object:

Scheme 1: create an M file first. In the M file, the main function is a serial. Fopen, fclose, fread, delete, et al. The functions include creating the serial port data, starting the serial port data, closing the serial port data, reading and writing the information in the serial port, deleting the corresponding serial port, and being used to write the packaging and sending program, data receiving and unpacking program, etc. The corresponding data in the M file. At the DSP end, similarly, by burning the program into the DSP and running both the MATLAB and DSP end programs, the corresponding communication can be established to achieve data exchange. This scheme enables real-time communication with DSP using M files, and processes data in real time. Generally used where the algorithm needs to be calculated in an M file.

Scheme 2: create the man-machine interface, use the callback module to write the callback function, and realize the serial port communication. Similar to Scheme 1, the M files are used to communicate with the DSP. In this scheme, the human-machine interface is created using the GUI module of MATLAB. On the one hand, the data can be monitored and displayed in real time; on the other hand, the communication parameters can be modified directly in the host computer interface, which is beneficial to increase the convenience of use.

Scheme 3: Establish communication through the SCI serial port module. This scheme differs from schemes 1 and 2 in that it can send and receive data directly with a DSP in the Simulink without the need for M files. This scheme uses Simulink for circuit simulation, DSP as controller and the associated data processing operations in DSP. Simulink And DSP are combined for hardware-in-loop simulation.

Therefore, scheme 3 is adopted to design the serial communication scheme of the modular DAB converter semi-physical simulation system, and the communication architecture design is shown in Figure 3. At the Simulink end, the SCI module can transmit real-time automatic monitoring information such as outlet current change, outlet voltage and input current. At the DSP end, the SCI module receives and processes the data to obtain the optimal shift ratio [D1mD2m] and sends it to the Simulink-end circuit model for the control of the circuit.

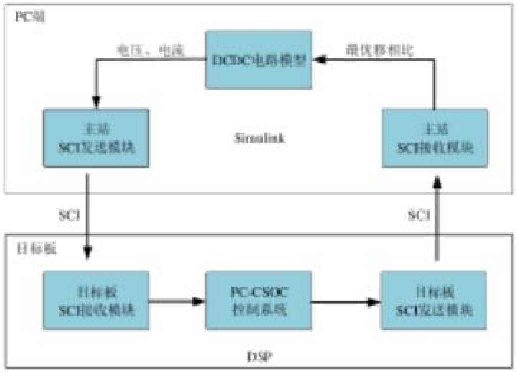

Figure 3. Design of the system communication architecture

4. Simulation validation of hybrid three-level DAB optimized modulation

To verify the correctness and validity of the optimization control as described above, the corresponding simulation model was built in the PLECS platform, and the simulation parameters are shown in the table4 as shown.

Table4 Outside 4 Hybrid three-level DAB simulation parameters

parameter	parameterdescription	numeric value
v_1	Less effective field you	450V
v_2	High voltage side voltage	200V
f_s	Low voltage side voltage	100kHz
L	switching frequency	20pH
N	leakage inductance	1:1

In the forward operation mode, when following the table4The above circuit parameters shown, substituting the optimization control method to the hybrid three-level DAB, the waveform of the voltage vp (t) and vst) on the magnetic element and the current i (t) on the inductance under light and medium load conditions are shown in the figure4. graph4(A) It is the waveform under light load, where in the mixed three-level side of the voltage bridge arm, there is no V level, and only 0 level and V / 2 level. As the power increases, when the converter works in the intermediate-load mode, the duty cycle of V level gradually increases, while the duty cycle of O level and V / 2 level decreases. At the same time, on the high current side, the current is almost 0 when the switch tube is closed, which greatly reduces the shutdown loss of the MOS tube. Under the light load condition, when the high voltage side switch pipe is opened, the current flowing through the body diode is too small to fully realize ZVS, but with the increase of power value, the switch occursThe phenomenon that the tube cannot be completely soft switched is improved. In the medium load area, all devices on the high voltage side can realize ZVS. At the same time, in the hybrid three-level DAB, due to the use of more switching devices, the waveform of the inductive current changes from the triangular wave in the two-level DAB to the polygon, the peak current decreases, and the current impact on the device is reduced.

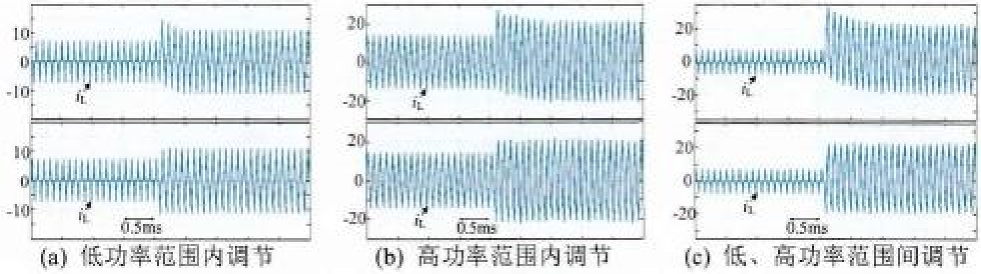

Figure 4-1 Transient current simulation waveform when the power increases

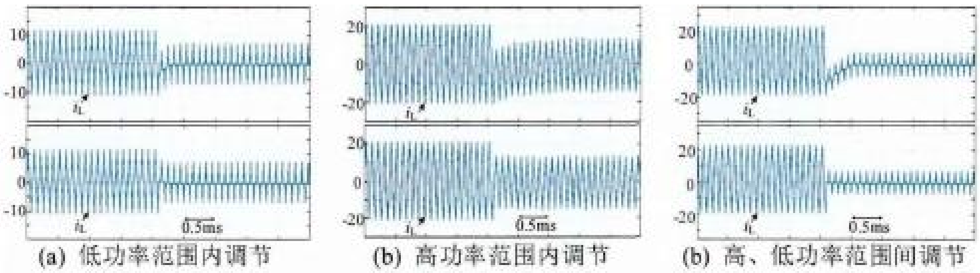

Figure 4-2 Simulation waveform of transient current when power decreases

5. Summary of this article

In order to solve the instability and intermittence of renewable energy sources, a feasible way is to combine renewable energy systems with energy storage units to build large-scale energy storage systems. Among them, the dual active bridge converter is the core equipment, because of its high efficiency, simple control, easy expansion and other advantages, it is widely used in energy storage system, distributed generation system and other scenarios. It has become a research hotspot in recent years. This paper studies the dynamic performance and steady-state performance. The specific work and conclusions are as follows:

(1) It has studied the DAB converter under SPS control, DPS control and EPS control, analyzed its working principle and working state, deduced the basic laws of primary and secondary voltage and inductance current, and established a mathematical model.

(2) Study and compare the transmission power and current stress characteristics of DAB converter under SPS control, DPS control and EPS control system: analyzed the DE algorithm and PSO algorithm, and proposed the collaborative hybrid algorithm IDEPSO algorithm according to the advantages of the two algorithms. Performance tests showed that, IDEPSO The optimization effect of the algorithm is good; To achieve the optimal control of the current stress while meeting the delivery power requirements, Establishing mathematical models of the optimal phase shift and current stress, Make the current stress optimization problem a mathematical education problem, The control strategy of current stress optimization based on IDPSO algorithm is given: in the full power range, Current stress is controlled in SPS control, DPS control, compared with EPS control and the optimal current stress control based on the IDPSO algorithm, Find the minimum current stress of the DAB converter under the optimal current stress control

based on the IDPSO algorithm; compare the current stress at different voltage transmission ratios under the four control strategies, Found that when the voltage transmission is larger than k, The optimization effect of the current stress under the optimal current stress control based on the IDEPSO algorithm is more obvious.

(3) Since the traditional single DAB converter cannot achieve good power transmission conditions in a high power environment, the modular dual DAB automatic converter is usually used to expand its transmission capacity. When the main circuit parameters of the modular DAB automatic converter are different, the PCEC management strategy is proposed to balance the energy of the converter. When the total output capacity of the modular DAB autoconverter is large, the OPCC management strategy is proposed to avoid overpower operation. It enhances the dynamic performance of the system and reduces the adjustment time. The proposed strategy is combined with the optimal current stress control technique based on the IDEPSO algorithm to provide a PC-CSOC management strategy, while optimizing the steady-state characteristics and dynamic performance of the modular DAB autoconverter to improve the efficiency of the autoconverter.

(4) The semi-physical simulation platform of modular DAB converter based on DSP and Simulink was built, and the modeling design scheme was adopted to realize the semi-physical simulation of modular DAB converter PC-CSOC control strategy based on Simulink, which verified the correctness of the control strategy.

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