회생모드가 없는 단일전원 27레벨 캐스케이드 H-브리지 인버터

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A Pre-Regulated Single-Sourced 27-level ACHB Inverter without Regeneration

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ABSTRACT

In this paper, a single-sourced PV PCS using the trinary asymmetric MLI with a single-ended pre-regulator is proposed. Trinary based asymmetric CHB inverters provide higher output levels for the same number of cells compared to other CHB inverters. However, there is an issue of regeneration with trinary asymmetric inverters and this complicates the system with requirement of bi-directional converters at the input. Modified commutation strategies have been used to remove the regeneration issue with compromise in THD. The single-ended pre-regulator provides the isolated dc-link voltage for the individual H-bridge cells with the advantage of having a single switch and magnetic component. This implementation increases the magnetic utilization of the inductor core and reduces the switching loss in the pre-regulator and also the reduced parts count contributes to the cost competiveness of the proposed PCS. The proposed PV PCS has been verified using simulation results in this paper.

1. Introduction

Multilevel inverter (MLI) based renewable energy systems have seen an increase of interest in literature due to its inherent advantages like, high quality output and reduced stress on components. Among the several MLI topologies, cascaded H-bridge (CHB) based inverters have been preferred in renewable energy systems due to their ease of integration. The CHB inverters are classified into symmetric and asymmetric types based on the dc-link voltage and operating frequency of individual H-bridge cells. While the symmetric CHB inverters are modular in nature, the asymmetric CHB inverters provide higher number of voltage levels in the output for the same number of H-bridge cells. The asymmetric CHB inverters are further classified into binary and trinary inverters based on the ratio of the individual dc-link voltages.

In this paper a 27-level trinary asymmetric inverter with the dc-link voltage ratio of 1:3:9 is utilized. The conventional modulation strategy used for this inverter is the nearest level modulation (NLM) technique. NLM operates by shifting the voltage levels of the individual H-bridge and produces a staircase output without use of high-frequency PWM switching. This ensures high efficiency and low THD at higher modulation index (m_a) values. However this modulation has a drawback of regeneration in the auxiliary H-bridge cells (see Fig.1). The fundamental output of the auxiliary H-bridge cells becomes negative at certain values of m_a. Hence to mitigate this problem, PCS include either bi-directional converters in the auxiliary inputs or modified commutation strategies to avoid the regeneration problem. The use of bi-directional converters affects the cost, size and efficiency of the PCS. Previous implementation in single-sourced systems used high-frequency link (HFL) and individual rectifiers for H-bridge cells have been discussed in literature.

In this paper a PCS using trinary 27-level inverter without regeneration by implementing modified commutation strategy and a unidirectional single-ended multi output pre-regulator is proposed. The pre-regulator consists of a single switch and single-magnetic component, hence improving the cost competiveness and efficiency and reducing the size of the PCS. Also the dc-link voltage provided the pre-regulator is fixed by the turns ratio (n) of the transformer irrespective of DCM/CCM operation. Hence sensors and controllers for the individual dc-link voltages can be avoided in this implementation.

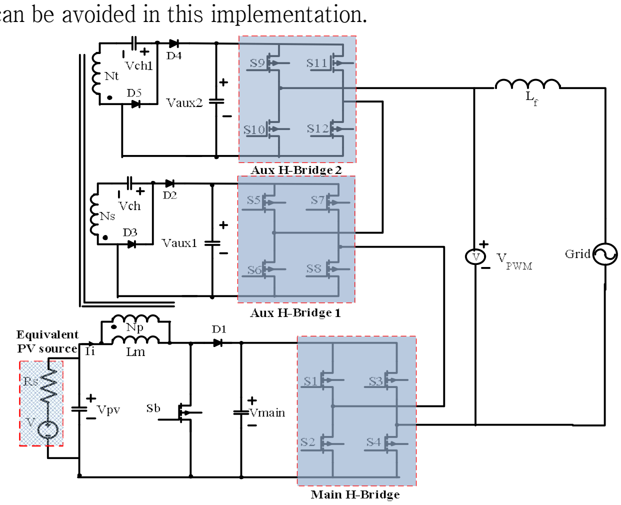

Fig 1. Circuit diagram of proposed PCS with 27-level trinary inverter and single-ended multi output pre-regulator in grid-connection.

2. Operating Principle

The circuit diagram for the proposed PCS with trinary 27-level inverter and single-ended pre-regulator is shown in Figure 1. The operation of the two stages in the PCS has been discussed below.

2.1 Single-ended multi output pre-regulator

Boost DC-DC converter with charge pumped output have been used in PV systems [1]. The pre-stage boost converter inductor is coupled with two charge-pump circuits using secondary and tertiary windings. This transformer improves the magnetic utilization in the regulator and also provides isolation necessary for the auxiliary dc-link voltages. The output voltage of the charge pump circuits depends on the transformer ratio as shown below

$$V_{aux1} = \frac{1}{(1-D)}\left(\frac{N_s}{N_p}\right) \qquad (1)$$

$$V_{aux2} = \frac{1}{(1-D)}\left(\frac{N_t}{N_p}\right) \qquad (2)$$

The energy is stored in the boost inductor and the charge pump capacitor when switch (Sb) turns ON. And similarly the stored energy is discharged when the switch turns OFF. Also by fixing the boost converter output, the charge pump output voltages are also fixed by the ratio of the multi-winding transformer ratio. Hence the auxiliary dc-link voltages are maintained irrespective of the CCM/DCM operating modes.

2.2 Asymmetric Trinary Inverter

In case of asymmetric trinary inverters the number of output voltage levels is 3^N, with N number of H-bridge cells. Trinary inverters with conventional NLM technique have the issue of regeneration at certain m_a values. Regeneration happens in auxiliary H-bridge cells due the fact that the fundamental output voltage component goes below zero for several intervals in NLM technique. Since a unidirectional pre-regulator is used in the proposed PCS, modified modulation strategies should be used to avoid regeneration. Modulation technique using firing angles obtained by using non-linear constraints on the individual H-bridge outputs have been used in literature [2]. The fundamental output voltage of all the three H-bridge cells are restricted to a value greater than zero in this technique.

The non-linear equations are solved using fmincon (large scale algorithm solver) tool in MATLAB. Minimizing the THD of the combined inverter output is used as the objective function, while the important condition of restricting the individual fundamental outputs are given as non-linear constraints in the solver. The firing angles are obtained for varying m_a values and loaded in truth table for modulation. The modified scheme is tested in simulation with a resistive load (50 Ω) and the dc-link voltages fixed as: V_{main}=225V, V_{aux1}=75V, V_{aux2}=25V respectively. The graph in Fig.2 shows the increase in THD due to the modified modulation scheme as expected. However the graphs in Fig.3 show that the regeneration issue is avoided in the modified scheme by restricting the power in auxiliary H-bridge cells above zero during regenerative regions. Fig.4 shows the simulation result of inverter and charge-pump output voltages with m_a 0.7.

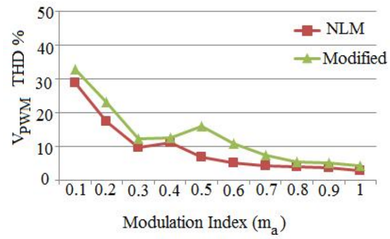

Fig 2. Comparison of THD between NLM and modified.

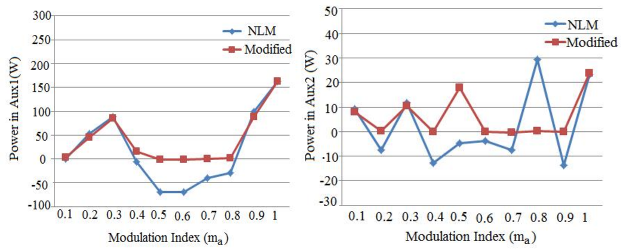

Fig 3. Power processed in Auxiliary H-bridge cells for varying m_a.

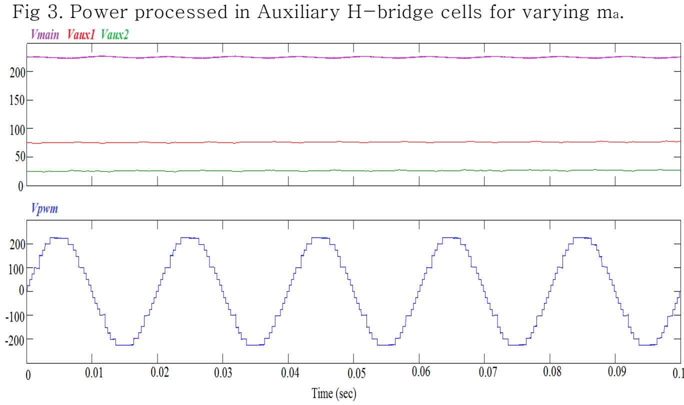

Fig 4. Inverter output V_{pwm} and dc-link voltages V_{main}, V_{aux1}, V_{aux2}.

3. Conclusion

In this paper a single-sourced 27-level asymmetric CHB MLI without regeneration is proposed. The dc-link voltages are pre-regulated using a single-ended multi output charge pump circuit, thereby ensuring cost competiveness and high efficiency. The system is tested in simulation with a modified modulation scheme to avoid regeneration issue.

References

[1] Woo-Young Choi and Jae-Yeon Choi "High-Efficiency Power Conditioning System for Grid-Connected Photovoltaic Modules", JOURNAL OF POWER ELECTRONICS, Vol. 11, No. 4, 561-567p, 2011.

[2] Espinosa E. Ramirez. R, "A novel modulation technique for asymmetric multi-cell inverters of 27-level without regeneration", IECON2012, IEEE IES, 123-128p, 2012.