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An Analysis of Multilevel Converter for Faster Current Control in a DC Micro grid with Extremely Low-Impedance Interconnections

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***Abstract:** Improved power converter configurations and semiconductors innovation capable of driving the required power have emerged in response to the rising global need for energy. It is still a constant endeavour to create semiconductors with greater current or voltage power to propel high power systems. In this way, modern gadgets can handle high voltage or current with ease. Traditional high-voltage semiconductor-based power converter schemes face stiff opposition from innovative medium-voltage device-based alternatives. DC microgrids, with their very limited line impedance, are developing as the upcoming type of small-scale power transmission connections. Due to this phenomenon, even a little change in voltage can create significant currents in microgrids, making quick rapid reaction and accurate power flow regulation essential. In order to provide fast and precise power flow regulation in a dc microgrid, this research employs multi-level converters as the controllers. A multilevel converter allows for a compact output filter. In addition, the final LC filter of a MLC that satisfies a current ripple demand has been designed and is presented in this work. In comparison to traditional two-level converters, we were able to demonstrate that a multi-level converter with a more compact filter may provide high-speed & high-precision power flow regulation under low line impedance situations. Using the simulation results from MATLAB/Simulink, the overall performance of every output current is assessed in the system response, taking into account the transient variations in the power flow.*

***Keywords:** DC Microgrid, Multilevel Converter (MLC), Power Flow Control (PFC).*

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1. INTRODUCTION

The need for converting electric power exists in a wide range of contemporary uses. Everything from personal electronics like laptops, cell phone chargers, and white goods to traction motors, steel mills, and even the transport of enormous quantities of electricity via electrical networks. Given its widespread use, power conversion must maximise efficiency to prevent waste of scarce resources and lessen the global effect of human industry. A lot of work has been achieved during latest days towards improved efficiency of power semiconductor process, such as novel designs, control approaches, and even advanced technologies are researched. Power electronic technologies such an adjustable speed drive, FACTS device, UPS, Statcom, DVR, electric car, and renewable energy sources all need multi-level inverters/converters. Many diverse forms of renewable energy, including solar panels, wind turbines, geothermal heat, hydropower, biomass, and so on, are now in use and being developed.

This concept is depicted in Fig. 1, in which MLCs constructed using developed medium-power electronics compete with traditional power converters utilising high-power electronics that are still in the early stages of their development. As a result of its ability to provide high output power while making use of established medium power circuit design, MLCs have emerged as a viable option for use in modern power requirements.

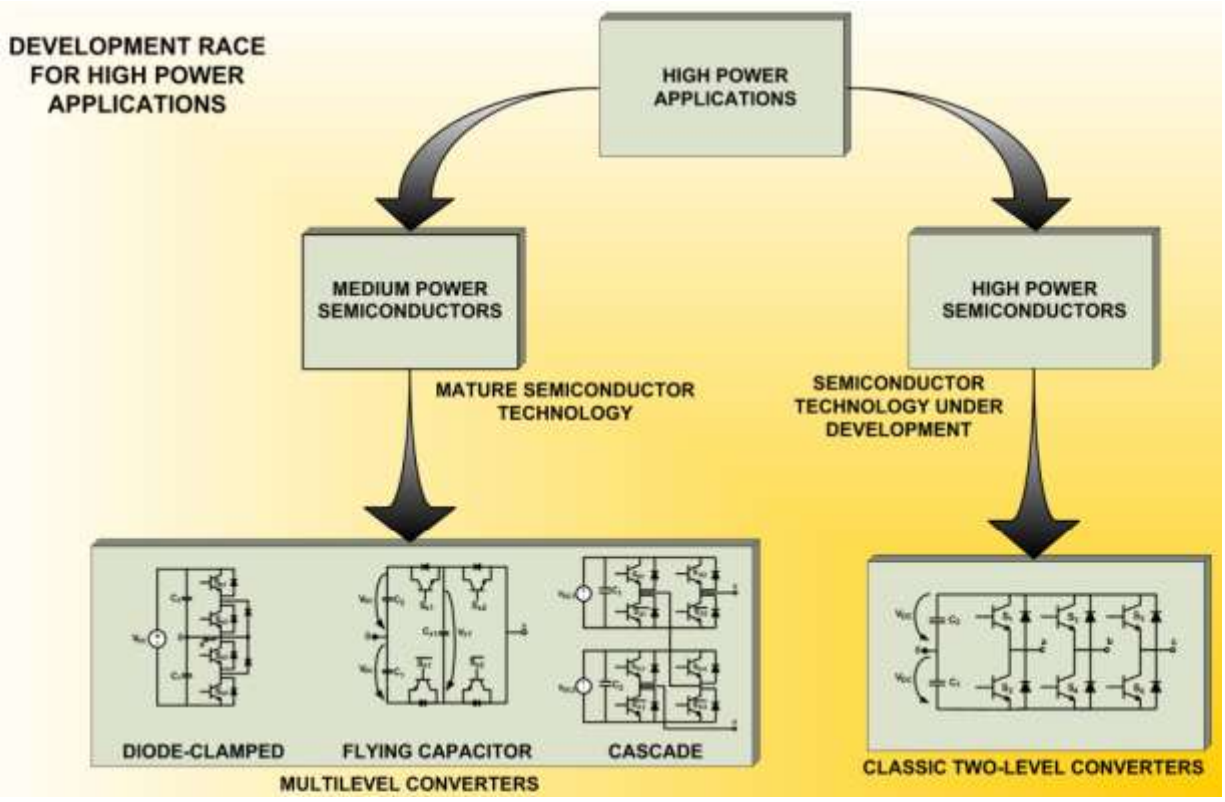

Fig.1: Traditional two-level power converters, in contrast to the usual MLCs.

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Microgrids need a fast converter with fine power system management to get around these restrictions. Large LC filters, however, make it difficult to quickly adjust flow of power, even when the standard total power or load circumstances undergo a dramatic shift. In this research, we use a multi-level converter to improve the efficiency and accuracy of power flow in a dc microgrid at high speeds. And without a filter, an m-level converter may provide an electrical output with m-steps. Thus, it is evident that as m grows, the ripple content in the dc output voltage may be reduced to 1/mth of what it was with the 2-level converter, allowing for a smaller output filter. Research on incorporating multi-level converters into DC microgrids has been conducted. However, there are no reports of research into the use of several multi-level converters in the construction of a dc network. Working with the level count as one of the design criteria, this research looks at the process of designing a power flow controller for a dc small scale grid. This research makes a significant contribution by developing a thorough design for converters and LC filters for the dc micro grid that takes into account the level count. In addition, a dc network with many multi-level converters is built and used in tests.

Converter Topologies

Comparing a MLC to the standard and widely used two-level converter reveals significant benefits for the MLC. These benefits centre primarily on enhancements to the quality of the output signals and an expansion in the converter's power rating. By contrasting the voltages produced by a 2-level and 7-level converter, we can see how much better the MLC performs. Neutral-Point-Clamped Converters, Flying-Capacitor Converters, and Cascaded H-Bridge Converters are the most typical MLC topologies. Many introductions to converter topologies architectures have been released in the form of studies. The 1980s saw the rise of converter power as a primary topic in the field of power electronics. In reality, study efforts to boost current have focused mostly on current source inverters.

Table-1 Based on implementation factors

	NPC	FC	CHB
Number of components	↑switches ↑diodes	↑switches ↑capacitors ↓diodes	↓switches ↓diodes isolated DC sources
Modularity	Low	High	High
Control complexity	Medium	High	High
Control concerns	Voltage balancing	Voltage setup	Power sharing
Fault tolerance	Difficult	Easy	Easy

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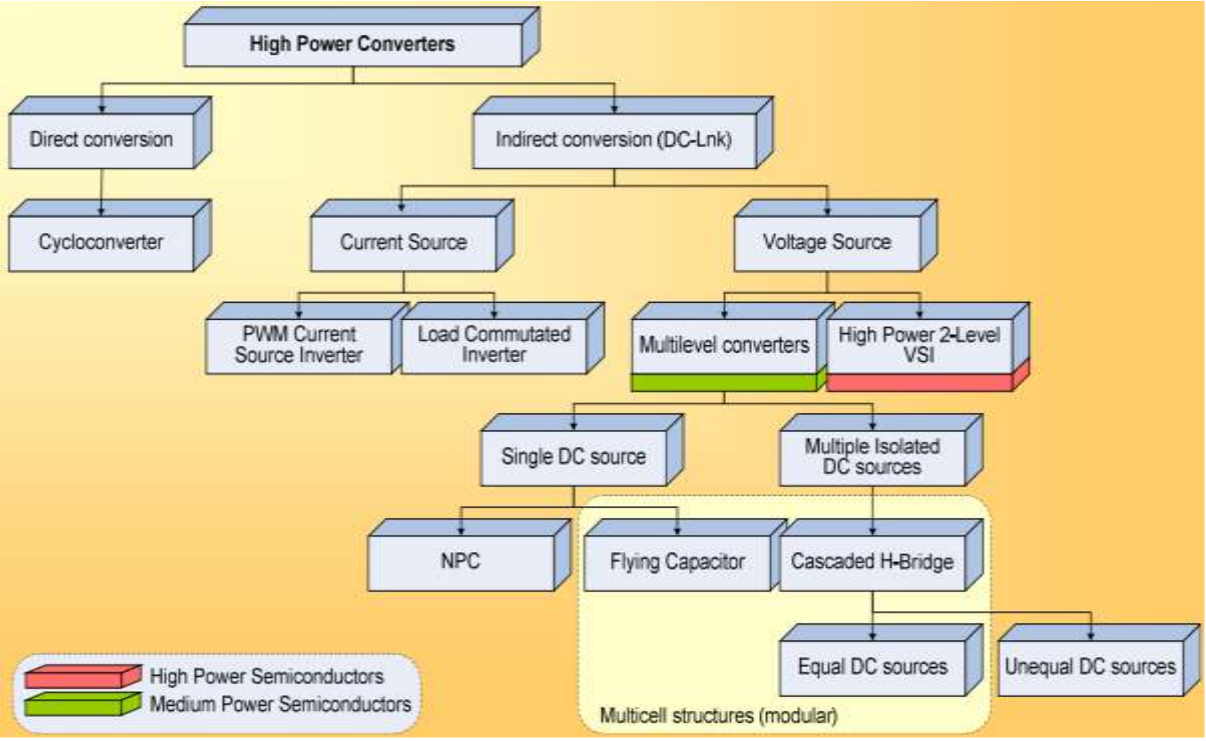

Fig.2: Classification of power converters.

Alternate authors, though, quickly started exploring the potential of elevating voltage rather than current. A. Nabae, I. Takahashi, and H. Akagi introduced the first Neutral-Point-Clamped PWM converter (NPC), also called a diode-clamped converter, in 1981 as an attempt to accomplish this goal through the use of a novel converter topology. In comparison to NPC, various MLCs range in a variety of ways, including the amount of components, modularity, control complexity, efficiency, and fault tolerance. These considerations, as indicated in Table I, can be used to determine the optimal MLC architecture for a particular design. As per Fig. 2, these converters belong to a subset of power converters designed for high-power usage. Multiple multilayer power conversion systems are now available as electronic instruments for high power industrial operations. However, despite the established benefits of multilayer converters for use as medium voltage drives, there has not been an industrial boom in the deployment of these energy systems in the electrical grid. Perhaps the sluggish global adoption of MLCs can be attributed to technological challenges like as reliability, efficiency, rising control complexity, and the development of simple, quick modulation techniques. Now that this technological hurdle has been cleared, MLCs are ready to be implemented as a developed power system in the electricity generation arena, thanks to the hard work of experts. Figure 3 depicts a brief overview of MLC-driven scenarios. In Fig. 4, we see a breakdown of the various modulation techniques used by multilevel inverters. Based on their primary mode of operation, modulation algorithms may be classified into either the state space vector domain, where the algorithms generate voltage vectors, or the time domain, where the algorithms generate voltage levels over a period of time.

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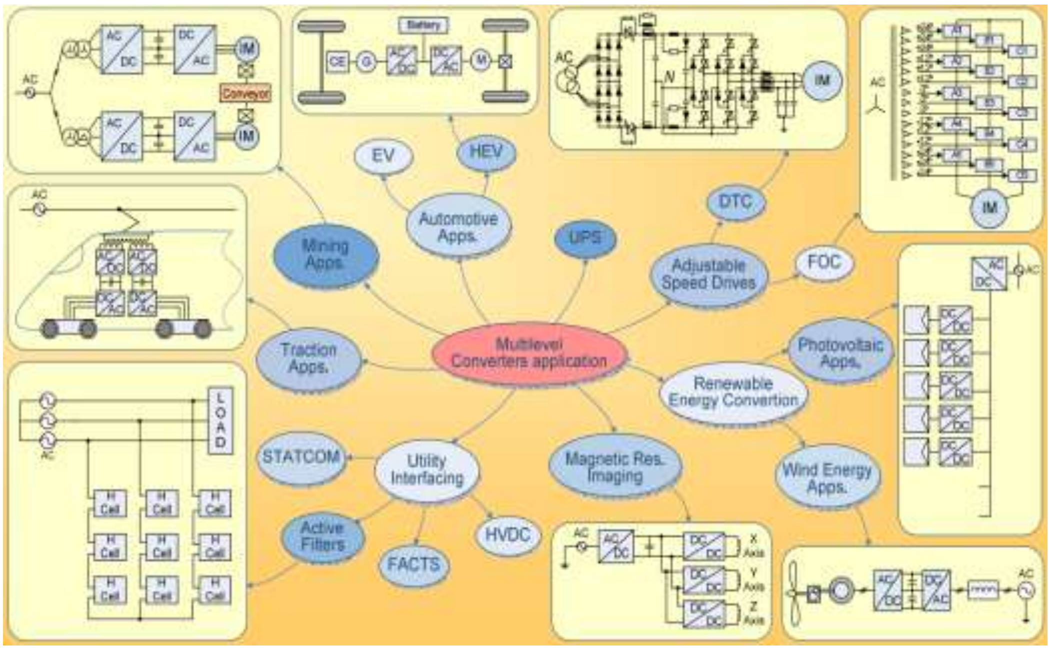

Fig.3: Overview of MLC applications.

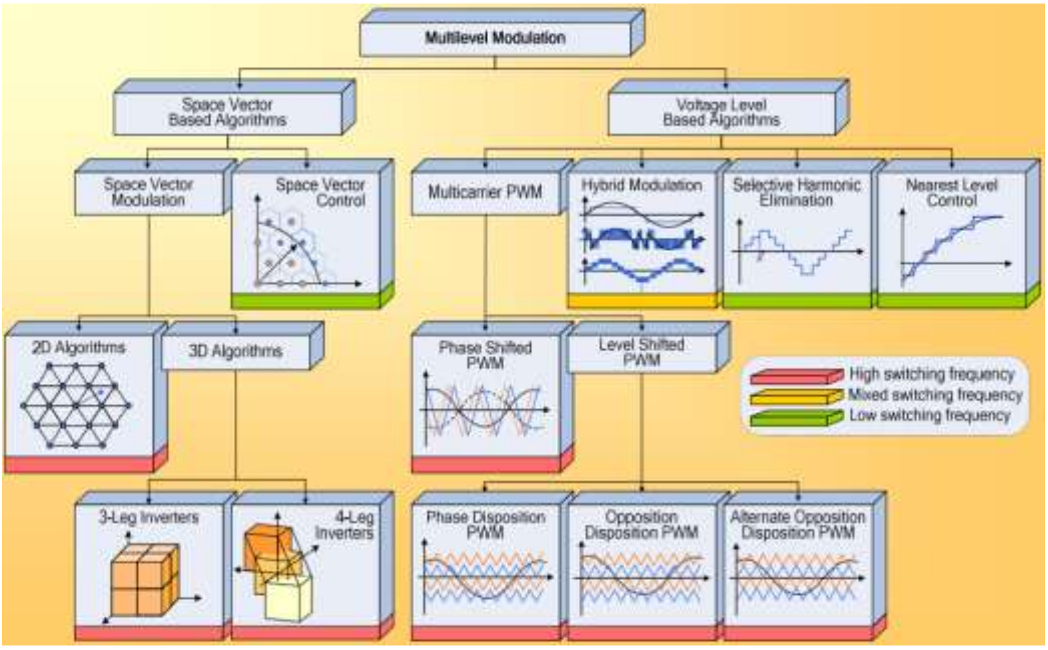

Fig.4: Classification of MLC modulations.

System Modelling

The expansion and spread of small-scale generating units has been facilitated by recent significant advancements in power electronic technology (DGs). Many TSOs and smart connected grids find the idea of an M-HVDC distribution networks appealing for all of the

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cross-sectional area of a dc line can be used to carry real power; unlike with ac lines, as well as dc lines are not constrained in their load ability by their surge impedance loading like their alternating current counterparts. In Fig. 5 we can see a circuit for studying the supply flow between two nodes, the smallest possible dc microgrid. Power sources (E1) and loads (E2) are shown in Fig. 5 together with the transmission lines and the power flow management (PFC). Two-level and multi-level topologies' circuit architectures are depicted in Fig. 6. Multi-level topologies of the flying-capacitor variety are employed as a case study in this investigation. Table I details the exact quantities of each circuit found in each converter. The primary components of a flying capacitor type m-level converter are (2m2) switches and (m2) flying capacitors. The overall transmission loss is virtually the same as that of the 2-level converters, despite the fact that a majority of series-connected switches grows in relation to the size of levels. Since the voltage stress on each switch is reduced in multi-level converters, switches with lower voltage ratings and lower on-state resistivity can be used. From the controller's perspective, more levels mean more complex gate signals and a higher switching frequency at the output using phase-shifted carrier modulation.

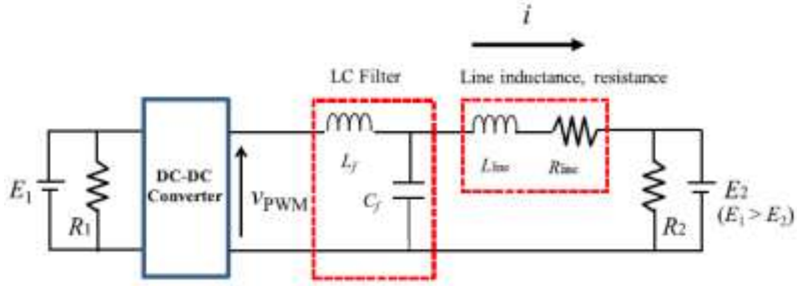

Fig.5: Topology between 2 nodes.

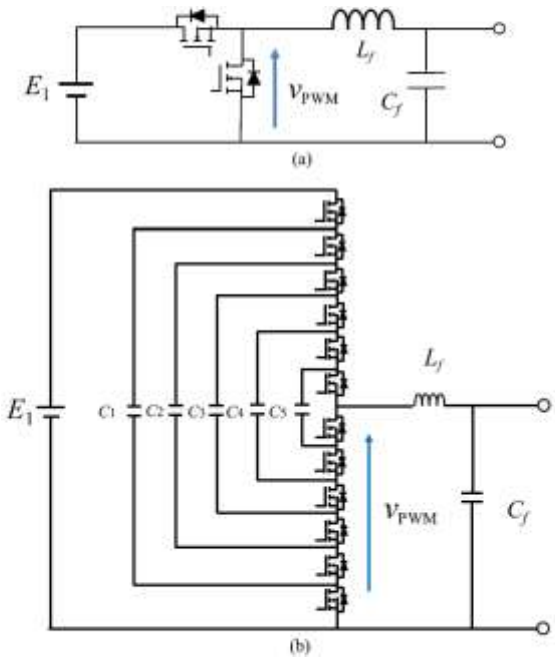

Fig.6: Power flow controller topology. (a) 2-level topology, (b) multilevel (7-level) topology.

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Table-1- Number of levels

The number of levels	2-level	7-level	m-level
Switching device	**2**	**12**	**2m-2**
Flying Capacitor	**-**	**5**	**m-2**
Output PWM switching frequency f_{PWM}	f_c	$6f_c$	$(m-1)f_c$

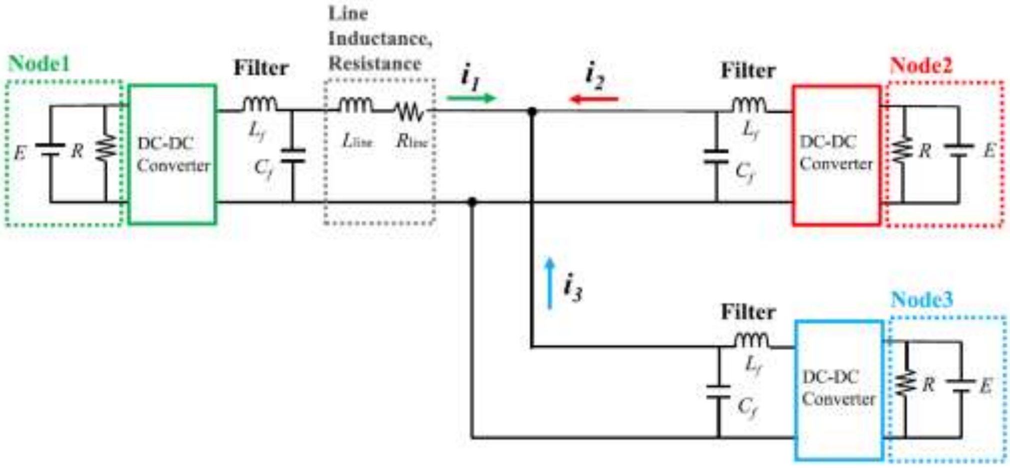

Fig.7: Proposed topology

The present control capacity of the 2-level and 7-level converters is evaluated using a simulation. For the purpose of this study, the dc microgrid is assumed to have a distribution network with three nodes and three converters, as seen in Fig. 7. In this circuit, three two-way power supplies are assuming the batteries. Power is transmitted between them through a distribution line, the stray inductance & equivalent resistance of which are a function of the line's physical length.

Neural structure controller:

Multi-level voltage-fed inverters have lately gained popularity in industry for high-power applications. Multi-level inverters outperform 2-level inverters with the same component switching frequency in terms of output spectrum. PWM generation, on the other hand, is more complicated. Voltage sharing of power electronic switches in multi-level inverters is simple to implement. Furthermore, voltage stress on every switching state is decreased using multi-level inverters. Multi-level inverters are gaining popularity due to intrinsic benefits such as minimal switching losses and less voltage stress, which translates in lower filter costs.

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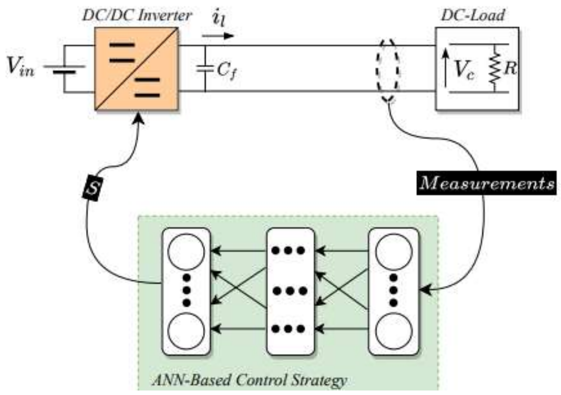
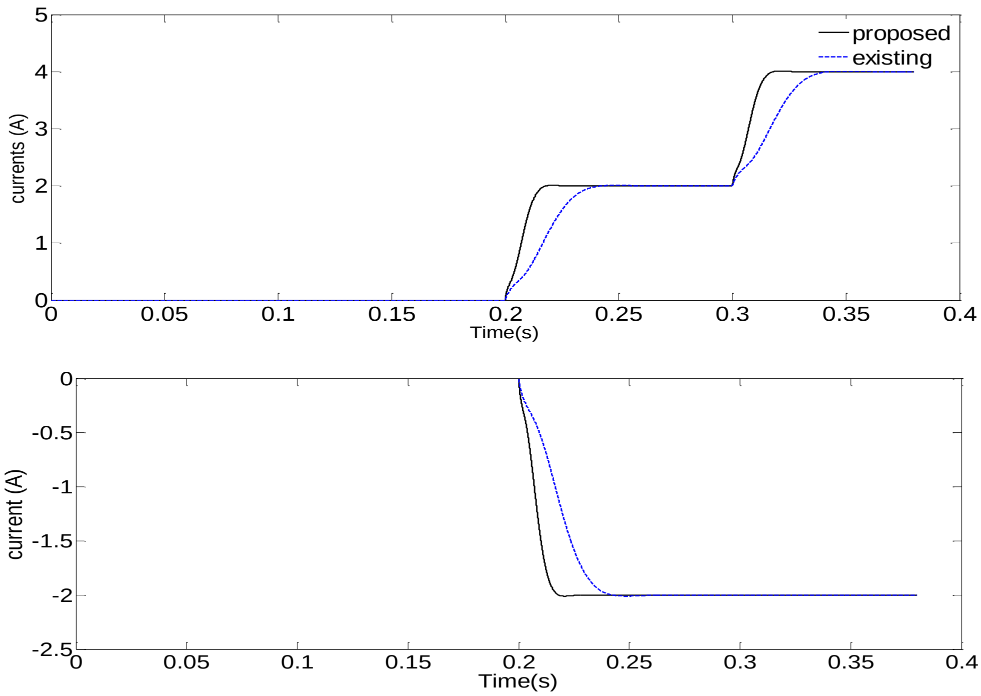


Fig.8: proposed control strategy.

Figure 8 depicts an overview of the suggested control strategy: the training phase combines to predict the transform output voltage transforms and data collecting under full-state observation. The data collected is utilized to train the ANN. The suggested control strategy's simulation results are also compared to the standard PI Controller.

2. SIMULATION RESULTS

For validation of the system is composed of 3 nodes and 3 converters, simulations of 2-level and 7-level converters with filters were planned and built, as shown in Fig. 7.
Case-1: 3 2 level transforms (fpwm =500 kHz).



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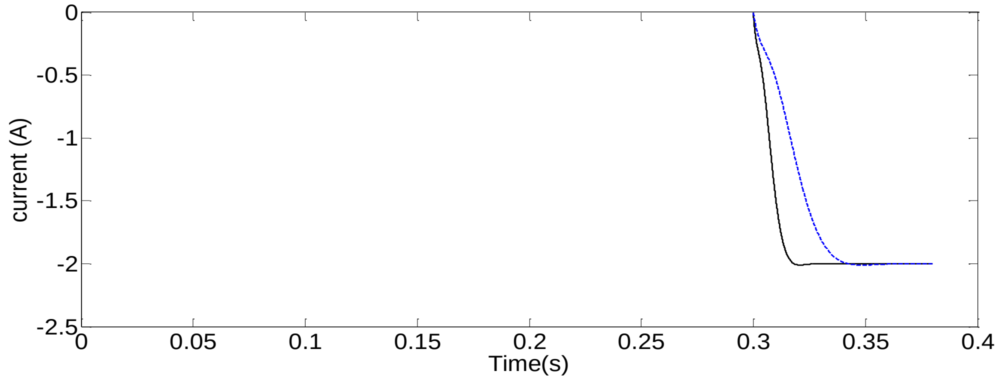

Fig.9: comparison waveforms of proposed and existing methods for 3-2 level converters (fpwm =500 kHz).

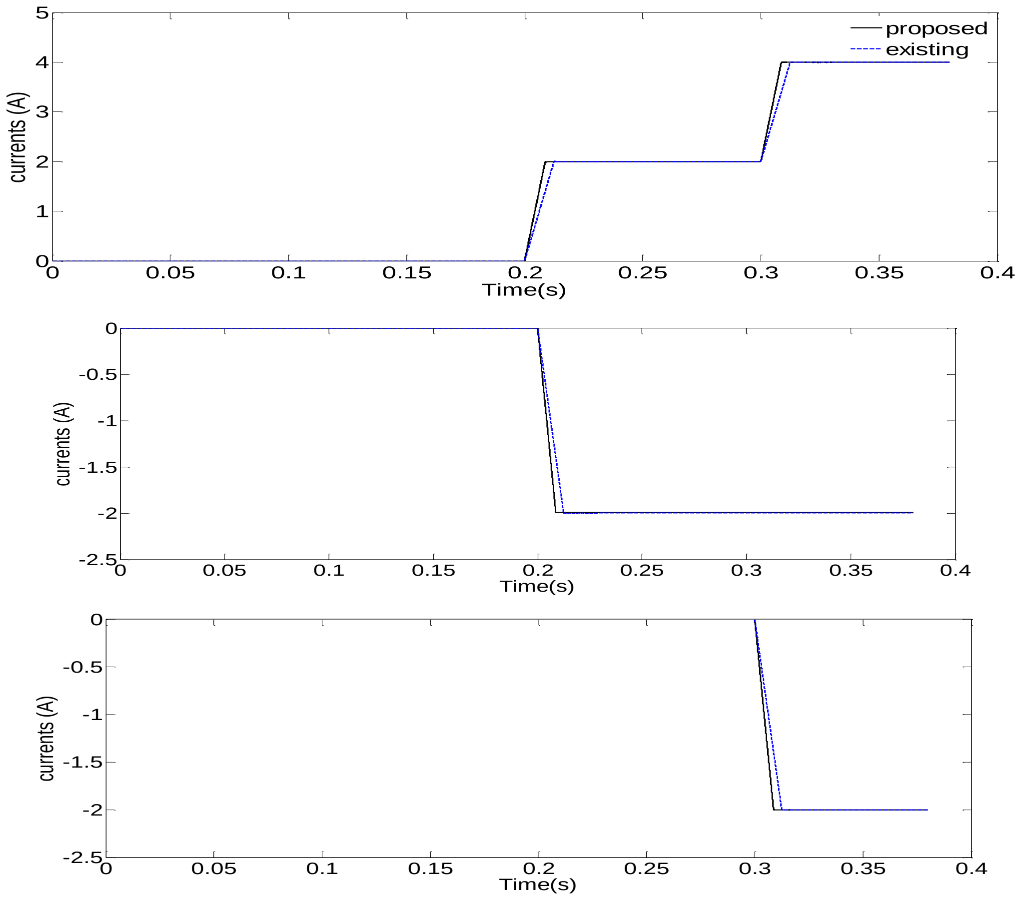

Fig.10: comparison waveforms of proposed and existing methods for 3-7 level converters (fpwm =500 kHz).

To begin, all currents are generally set to zero, implying that the output voltages of all 3 transforms are set to the same value. Second, a current of 2.0A is obtained from Node1 to

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Node2 by adjusting the output voltage of the transforms, hence keeping current i3 constant. Third, a current of 2.0A passes from Node1 to Node3, keeping current i2 constant at 2.0A. As a consequence, Node1's current of 4.0A is spread evenly (2.0A) to Nodes 2 and 3. Each transform's current-control system is based on a PI controller that uses feedback information from each inductor current. The settling time of the proposed 2 & 7-level transform is roughly one-fifth that of the existing 2 & 7-level transform, which is owing to the reduced time constant of the proposed 2 & 7-level transform's filter. Furthermore, the response values of i2 and i3 do not follow the reference values at the corresponding instants of the step shift (0.2 and 0.3 s); this is owing to the transform's response bandwidth constraint.

3. CONCLUSION

In recent years, MLCs have developed from a promising modern innovation to a competent, viable option for medium-voltage, high-power drives. These days, medium and high power applications benefit greatly from MLC topologies like NPC, FC, and CHB because to their impressive power quality, power range, modularity, and other qualities, which allow them to provide high-quality output signals. Since the market is gradually moving toward more potent and dispersed energy sources, now is the moment to place bets on this technology for both current and future power systems To provide quicker control method in a dc microgrid with very low-impedance interconnections, we looked at multi-level converters in this research. The number of data steps, the steady-state distortion, and the amplitude of the sudden shift in the output current were all taken into account throughout the power flow controller's output filter's design process. Through simulation and experiment, the current-control abilities of both the 2-level and 7-level converters were studied. Better current management is achieved by a power flow controller employing a multi-level converter, with current ripple maintained at a constant value, as determined by the research. Small-scale dc power systems stand to benefit greatly from the multilayer power flow controllers, which can regulate power flows more quickly while maintaining the same degree of stability. Simulations were used to look at the current-control abilities of both the 2-level and 7-level converters.

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