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Converters for Power Electronics in Variable Speed Pump Storage

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Abstract*: The power electronics method serves to regulate variable speed operation within variable speed pump storage systems according to this research. Research focused on reviewing different variable-speed pump storage systems by analyzing both power electronics converters and doubly fed asynchronous machines. The model uses Cyclo-converter and two-level along with three-level voltage source-converter and H-bridge cascaded eleven-level converters as power electronics converters. This analysis evaluates the speed variation together with total harmonic distortion appearing in rotor current of double-fed asynchronous machines for various converter types. The study confirms that the H bridge eleven level converter provides the best available solution. Every simulation model needed the PSIM software for execution.*

Keywords*: Double-fed asynchronous machine, cyclo-converter, Pump storage, variable speed, pulse width modulation and multilevel converter*

I. Introduction

The variable-speed pump storage system stands as the most efficient method to store extensive amounts of electrical energy at present. The implementation of variable-speed pump storage improves all aspects of power network control including balance and stability while enhancing energy efficiency. The two varieties of variable-speed pump storage systems include the single reversible pump turbine machine (the Francis machine) that performs as both pump and turbine simultaneously as well as the separate pump and turbine combination with the generator or motor connection (currently unused) [1]. The achievement of variable speed operations relies on a doubly fed adjustable speed pumped storage unit (DFASPSU) system according to [2] through [5].

The double fed induction machine operates as a variable speed adjustable speed doubly fed system that today serves wind generators. A depiction of the doubly fed adjustable speed pumped storage unit layout appears in Figure 1. A block transformer enables the power network to connect to the stator section of the doubly fed machine. A power electronics converter delivers electricity to the rotor and has its power source in a turbine containing moving blades. Research shows that a multilayer inverter serves as the power electronics converter for variable-speed pump storage applications in the present.

The three types of multilevel inverters include Diode clamped inverters along with H-bridge cascade inverters and flying capacitor inverters. The output voltage capabilities of multilayer inverters surpass those of traditional two-level inverters and cycle-converters while using the same switching frequency by providing exceptionally low distortion together with diminished dv/dt and smaller CM voltage. All previous variable speed operations for variable speed pump storage systems have used diode clamped in addition to H-bridge cascaded inverters.

A power system benefits considerably from variable speed operation of pumped storage because it enables power regulation during the pumping phase. The electrical machine's inertia in addition to the pump-turbine function leads to the core requirement of power electronics for controlling power at a quick responsiveness.

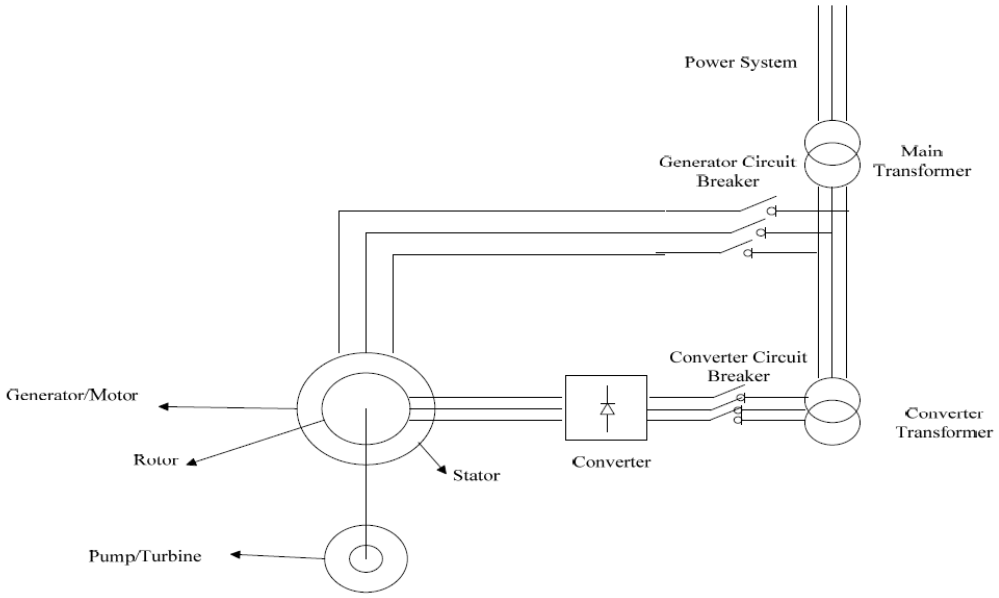

Fig 1: DFASPSU

II. Power Electronics Solutions

Power electronics converters that include cycle-conversion or back-to-back converters supplied power to the rotor of the induction machine at this time. The two kinds of back-to-back converters include three-level diode clamped converters and two-level converters. Variable-speed pump storage presently investigates the multilevel cascaded H-bridge converter as a potential new technological solution [6]. Cycloconverters function as AC to AC converters by transforming grid frequency between 50 or 60 Hz to low frequencies when controlling high-power synchronous applications that drive induction machines. During the late 1980s the company introduced and deployed cycloconverters to control speeds in hydroelectric plant variable-speed drives throughout Japanese facilities. The variable-speed pump storage system employs thyristor type GTO as its main component.

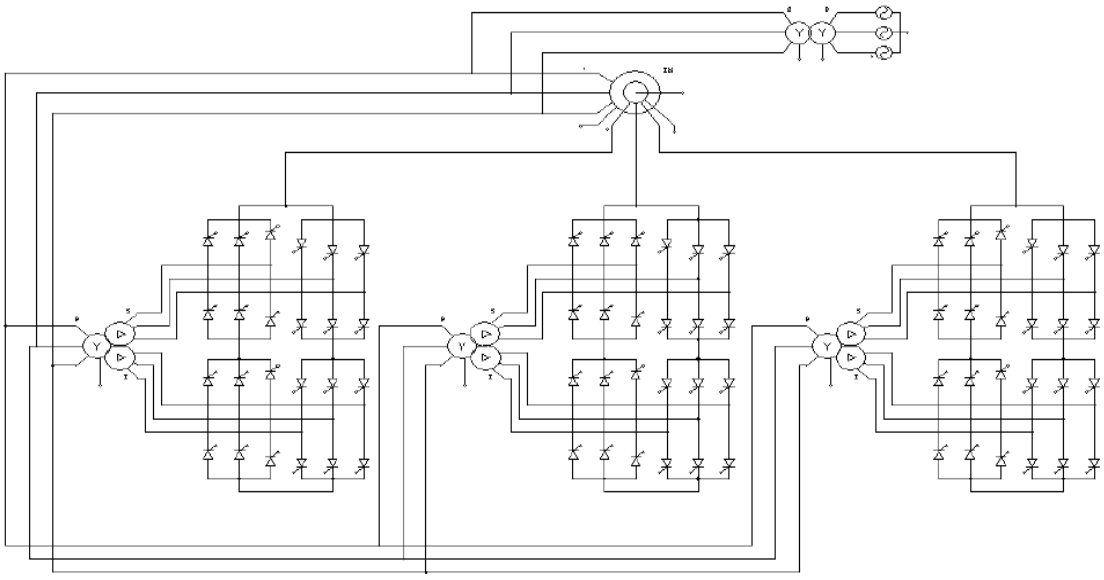

Fig 2: 3 phase-3 phase bridge cycloconverter

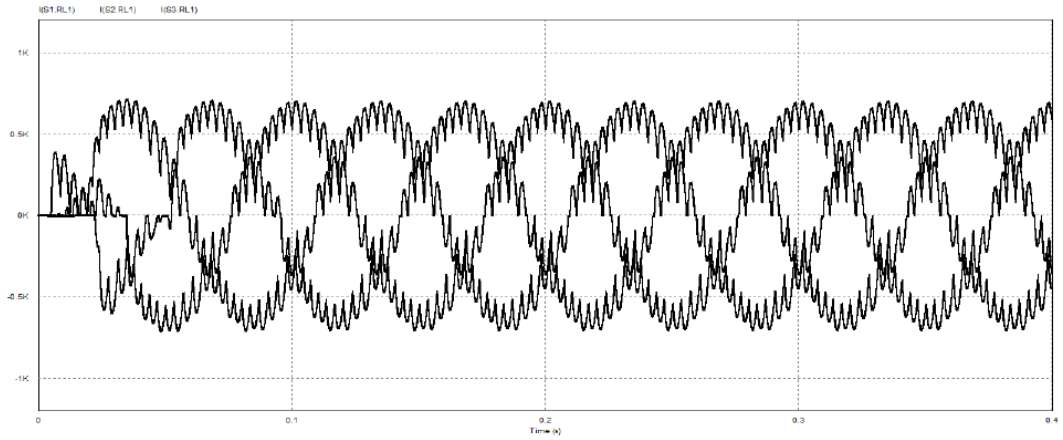

Fig 3: Rotor current from cycloconverter with THD 18.99%

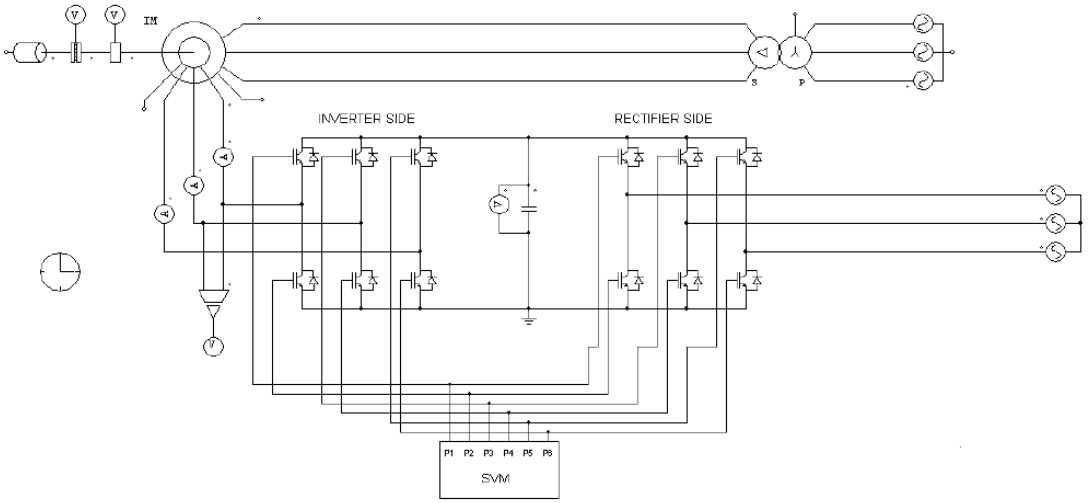

Fig 4: Back to back two levels AC/DC/AC circuit

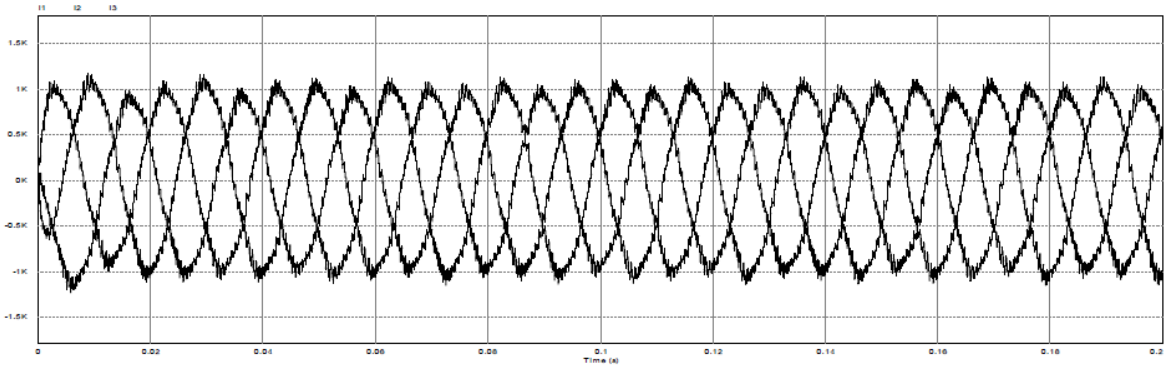

Fig 5: Rotors currents of two level VSI with THD 4.42%

III. Three Level Diode Clamped Voltage Source Inverter

The three-level voltage source inverter (AC-DC-AC) used for variable-speed pump storage operates under the circuit schematic shown in Figure 6. The selection of switching devices relies on IGBT, GCT, GTO, thyristor technology and GCT offered in practical applications. A variable speed operation results from connecting the rotor of the DFAM to the output of the inverter system. The switch control mechanisms for three-level voltage source inverters consist of SVM and carrier-based PWM. The simulation model implemented in PSIM relies on carrier-based PWM because the additional approach proves to be complex.

The Figure 7 illustrates the three-phase rotor currents which originate from the AC side. The THD performance of the three-level inverter surpasses both two-level voltage source inverters and cycloconverters. The main disadvantages of this technology stem from the requirement of high-speed clamping diodes which need to withstand the whole load current stream while also being subjected to intense reverse recovery pressures and presenting challenges when developing systems beyond three-level systems (five and seven).

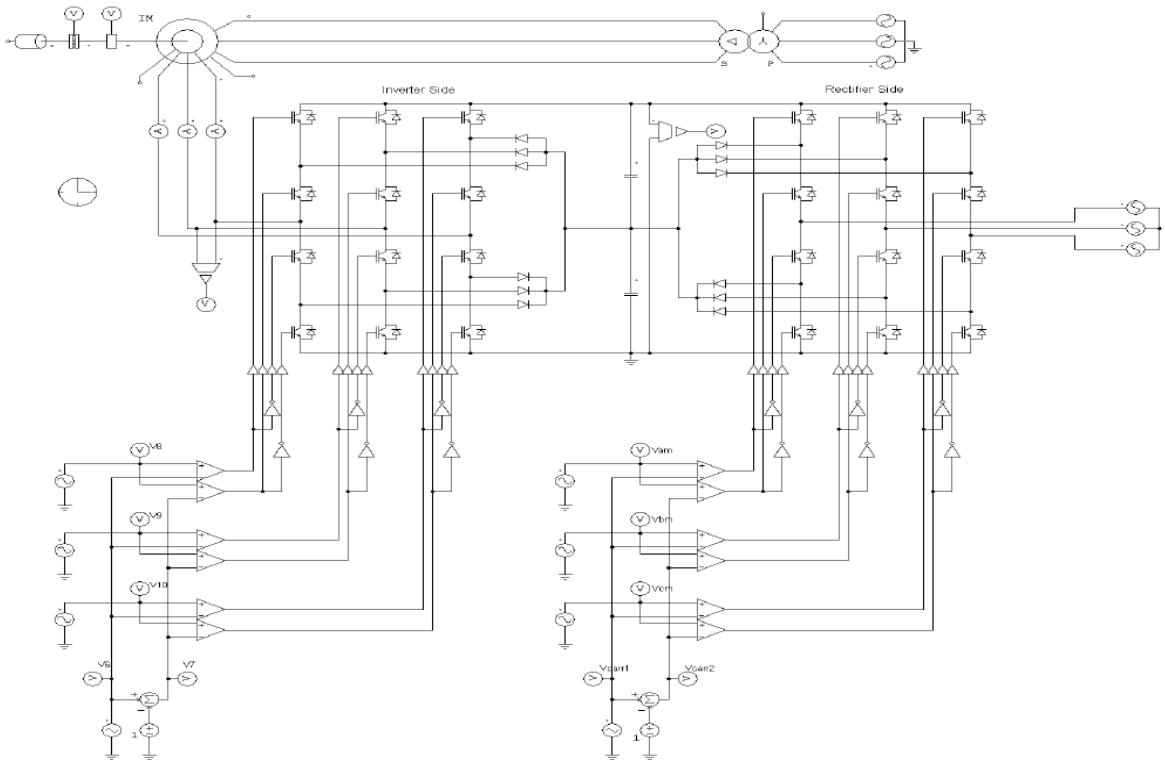

Fig 6: Back to back three levels AC/DC/AC circuit

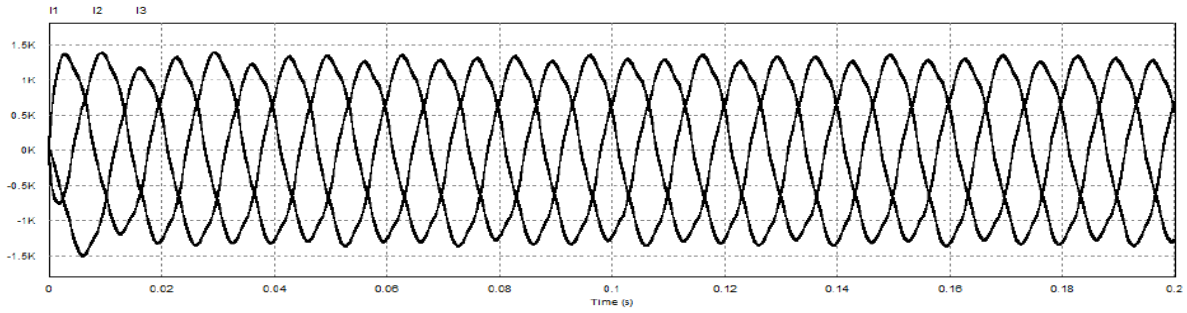

Fig 7: Rotors currents of three level VSI with THD 4.19%

As seen in Figure 8. A power cell contains a single-phase H-Bridge inverter and three-phase diode rectifier together with a dc capacity. Each phase consisting of five rated 690V cells generates phase voltage at 3450 V and line voltage at 6000 V respectively as shown in Figure 9.

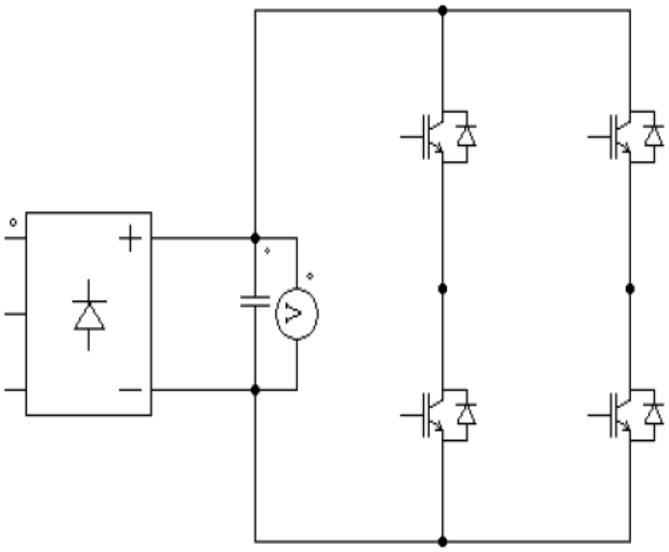

Fig 8: 11 levels H-bridge cascaded multilevel converter

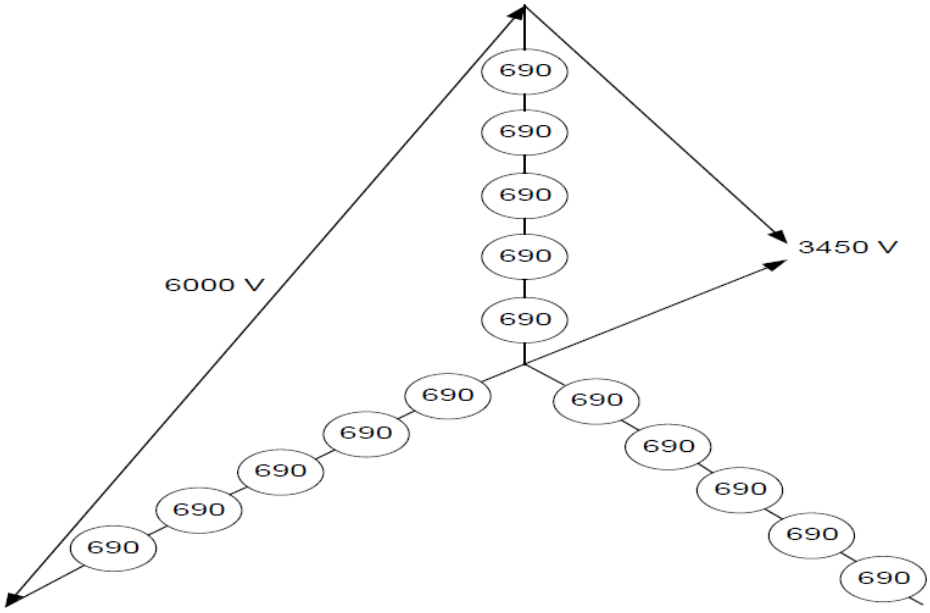

Fig 9: Phase and line voltages of power cell

High costs related to phase changing transformers together with the requirement for many cables stand as major limitations of multi-layer CHB drives. The Xiang Hong station of China utilizes an H-bridge cascaded multilevel converter for starting synchronous motors within its pumped storage power facilities. The figure below shows the rotor currents which power variable speed pump storage in figure 10.

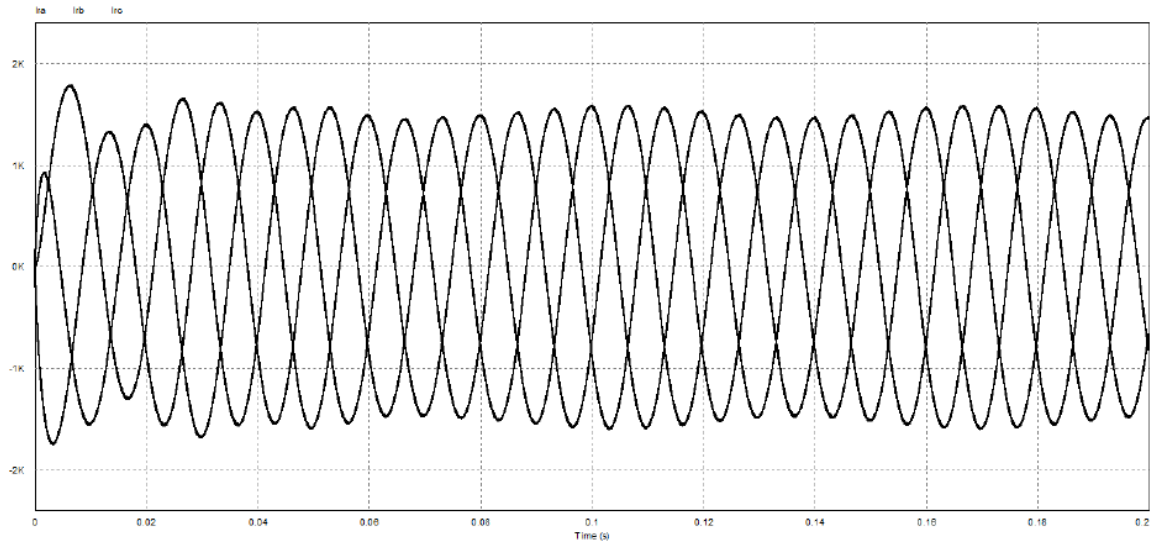

Fig 10: Rotors currents of H-bridge cascaded multilevel converter with THD 1.065%

The speed control of the wound rotor is illustrated through Figure 11 for a succession of three-level voltage source inverter and two-level voltage source inverter alongside the eleven-level H bridge cascaded inverter.

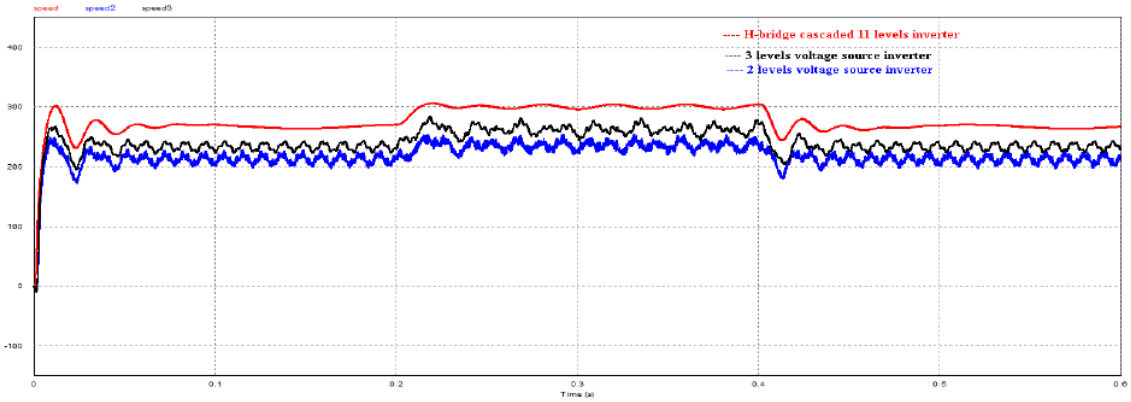

Fig 11: PSIM simulation of variable speed of three types of inverters used in variable speed pump storage

IV. Conclusion

An evaluation of power electronic converter technologies appropriate for variable-speed pump turbine operation has completed in this research. The analysis includes four power electronics converter types which include cyclo-converters, two-level, three-level back-to-back voltage source inverters and H-bridge cascaded multilevel inverters. The H-bridge cascaded multilevel converter proves superior to all other converter types in current evaluations. The converter reacts rapidly and produces lower dv/dt together with reduced current THD. The PSIM tool served for complete analysis of all model types.

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