# MATLAB Based Control of Active Power Exchange with Auxiliary Power Loop in a Single-Phase Cascaded Multilevel Converter-Based Energy Storage System

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**Abstract**

Cascaded multilevel converter (CMC)-based energy storage system, which consists of cascaded H-bridge converters and energy storage components, is a promising option to compensate fluctuating electric power of renewable energy. The cascaded converter cells and the LC branch form an auxiliary power loop, which could realize active power exchange between different cells. The operation principle of the powerexchange in the proposed energy storage system has been successfullyverified by simulation and experimental results.

**Keywords:**PIC microcontroller, Energy meter, inverter, Load, Inductor

## 1. Introduction.

The cascaded multilevel converters(CMC) is a promising solution to obtain high voltage from low-voltage devices. Since switching is between several smaller voltage levels, the CMC has lower dV/dt than two-level converters. Meanwhile, its modular structure allows the usage of low-cost switching devices with low electromagnetic interference, low total harmonic distribution at low frequency and high fault-tolerance capability. For this reason, CMC has been widely employed in high-power applications such as static synchronous compensator (STATCOM) and motor drivers. In recent years, its prominent structure makes it suitable for single-phase energy storage applications, which require obtaining high voltage from low-voltage devices, i.e., traction converter in HV with battery, regenerative breaking with EDLC. Compared to the traditional transformer-based multipulse converters, CMC reduces the voltages of individual energy storage unit.

In this project, there are energy storage systems which are given to single H-Bridge acting as inverters here. So the inverters are connected in series whose output is passed through a tuned filter which is again passed to an inductor and then to a load. We can also see waveforms of cascaded H-Bridges. Inverters are controlled through PIC Microcontroller. On MATLAB, We can see the waveforms of output voltage of cascaded H-Bridges.

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## 2. LITERATURE SURVEY

Although the number of active switches and control complexitywill increase, topology and redundancy allow CMC-basedconverters to achieve more than one goal within the imposedcontrol system. For example, the dc-link balancing control canbe realized without extra circuits. In most CMCapplications,the dc-link balancing is fundamental for the safe operationof the system. For CMCbased STATCOMs, adequate methodsformaintaining the balance of the capacitor voltages havebeen employed in the literature [1], [2]. For the CMC-basedenergy storage system (ESS), the internal impedance and theself-discharge rate are different in each energy storage component,i.e., battery cell or EDLC cell, because of themanufacturingdiscordances. In a series-connected configuration, thedifference of parameter between cells will result in unbalancedvoltage/state ofcharge (SOC). The unbalance of voltage/SOC
could reduce the performance of the ESS sincesome of thecells cannot provide the expectedactive power while otherscan. This situation could cause the destruction of the individualenergy storage component, and even the failure of the wholesystem. There have been some balancing circuits for seriesconnectedbattery/EDLC packs, which can be classified as passivebalancing circuits [3], [4]. The active balancing circuits could effectively equalizethe SOC/voltage within series-connected battery/EDLC bytransferring energy from cells to cells with dc–dc converters.
However, an additional balancing circuit not only increasessystem complexity but also reduces efficiency. Thus, dc-linkbalancing control strategies without additionalactive circuitshave been proposed in the literature for a CMC-based system.The voltage balancing methods of single-phase CMC batteryenergy storage system (BESS) based on staircase modulationhave been introduced in [5] and [6].

## 3. Implementation:

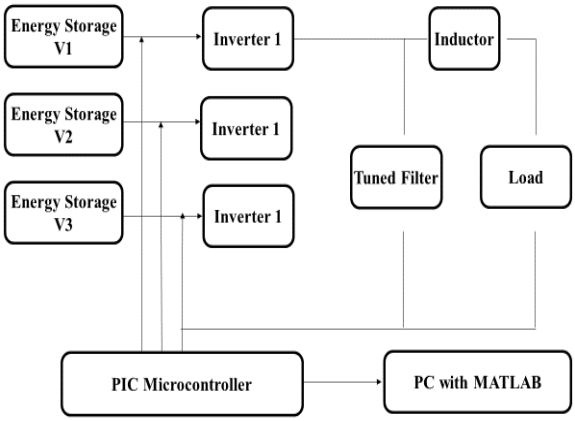


**Figure 1: Cascaded system**

The proposed single-phase CMC-based ESS is shown inFig. 1. The CMC includes *3*energystoragecomponents. An *LC* branch is paralleled with thecascaded inductor, tuned filter, which consists of $L_r$, $C_r$ , and$R_r$. The *LC*branch is tuned at resonant frequency $f_n$

**PIC microcontroller:**


**Figure 2: PIC microcontroller**

The PIC16F72 CMOS FLASH-based 8-bit microcontroller is upward compatible with PIC16C72B/74B/76/77,PIC16F873/874/876/877device s. It features 200 ns instruction execution, self-programming, an ICD, 2 Comparators, 8 channels of 8-bit Analog-to-Digital (A/D) converter, 2 capture/compare/PWM functions, a synchronous serial port that can be configured as either 3-wire SPI or 2-wire I2C bus, a USART, and a Parallel Slave Port. PIC16F72 is a RISC microcontroller, that means that it has a reduced set of instructions, more precisely 35 instructions.

**Energy storage device (Battery):**


**Figure 3: Rechargeable Battery**

A rechargeable battery, storage battery, or accumulator is a type of electrical battery. It comprises one or more electrochemical cells, and is a type of energy accumulator. It is known as a secondarycell because its electrochemical reactions are electrically reversible. Rechargeable batteries come in many different shapes and sizes, ranging from button cells to megawatt systems connected to stabilize an electrical distribution network. Several different combinations of chemicals are commonly used, including: lead–acid, nickel cadmium.

**Inverter:**

**H Bridge With switches as inverter:**

An H bridge is an electronic circuit that enables a voltage to be applied across a load in either direction. In H-bridge MOSFETS are used for controlling the voltage when DC to AC is converting.

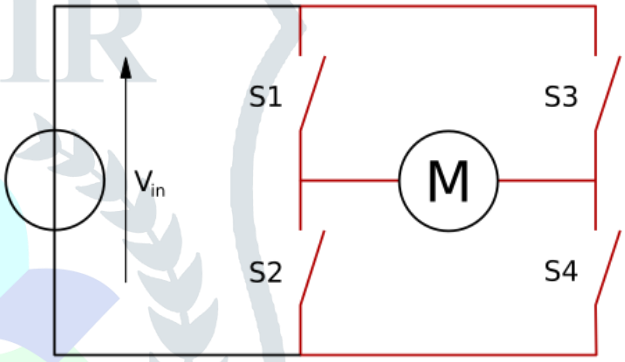


**Figure 4: H-bridge inverter**

When the switches S1 and S4 (according to the first figure) are closed (and S2 and S3 are open) a positive voltage will be applied across the motor. By opening S1 and S4 switches and closing S2 and S3 switches, this voltage is reversed, allowing reverse operation of the motor.

Using the nomenclature above, the switches S1 and S2 should never be closed at the same time, as this would cause a short circuit on the input voltage source. The same applies to the switches S3 and S4. This condition is known as shoot-through.

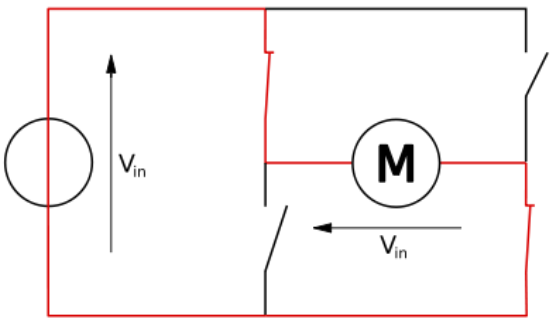


**Figure 5: H-bridge(S1 and S4 are ON)**

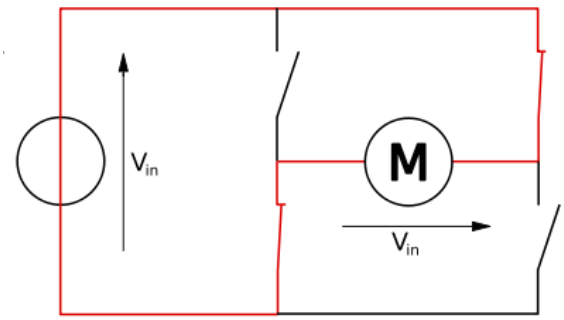


**Figure 5: H-bridge(S2 and S3 are ON)**

The H-bridge arrangement is generally used to reverse the polarity of the motor, but can also be used to 'brake' the motor, where the motor comes to a sudden stop, as the motor's terminals are shorted, or to let the motor 'free run' to a stop, as the motor is effectively disconnected from the circuit. The following table summarizes operation, with S1-S4 corresponding to the diagram above.

**Exhaust fan:**

**Figure 6: Exhaust fan**

The primary **purpose** for having an **exhaust fan** is to remove the moisture out of the room. These **fans** help to control and eliminate room odors. Additionally, they add to the safety of the home and its residents by reducing fumes from cleaning agents that could potentially cause health-related issues. In this project they used to eliminate moisture inside the robot cave.

**High power LED:**

**Figure 7: High power LED**

A **light-emitting diode** (**LED**) is a semiconductor light source. LEDs are used as indicator lamps in many devices. Like a normal diode, the LED consists of a chip of semiconducting material impregnated, or doped, with impurities to create a p-n junction. As in other diodes, current flows easily from the p-side, or anode, to the n-side, or cathode, but not in the reverse direction. Charge-carriers—electrons and holes—flow into the junction from electrodes with different voltages. When an electron meets a hole, it falls into a lower energy level, and releases energy in the form of a photon.

**MATLAB**

The name MATLAB stands for matrix laboratory. MATLAB (matrix laboratory) is a numerical computing environment and fourth-generation programming language. Developed by MathWorks, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java, and Fortran.

MATLAB can be used in a wide range of applications, including signal and image processing, communications, control design, test and measurement, financial modeling and analysis, and computational biology. For a million engineers and scientists in industry and academia, MATLAB is the language of technical computing.

**5. CONCLUSION**

The existing model presents an Integrating feature of all the hardware components. The presence of each and every module has been reasoned out and placed very carefully. Hence the contributing to the best working unit for "**MATLAB based Control of Active Power Exchange with Auxiliary Power Loop in a Single-Phase Cascaded Multilevel Converter-Based Energy Storage System**" has been designed perfectly. Thus, the project has been successfully designed and tested.

**Crystal oscillator:**

**Figure 11: Crystal oscillator**

An oscillator is an electronic circuit that produces a repetitive electronic signal. The maximum operating frequency of PIC Microcontrollers is 20 MHz Crystal oscillator is used in the project because of the fact that crystal is more stable to temperature than other types of oscillators.

**6. ACKNOWLEDGEMENT**

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