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ADVANCED DRIVE SYSTEM FOR DC MOTOR USING MULTILEVEL DC/DC BUCK CONVERTER CIRCUIT

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ABSTRACT
This project presents a new topology of clamped diode multilevel DC/DC buck power converterfor a DC motor system. The proposed converter circuit consists of four cascaded MOSFET power switcheswith three clamping diodes and four voltage sources (voltage cells) connected in series. The main objective ofthe new topology is to reduce current ripples and torque ripples that are associated with hard switching of thetraditional chopper circuit. When the voltage profile of this converter is applied on a DC motor, it positivelyaffects the performance of the DC motor armature current and the generated dynamic torque. The outputvoltage of the proposed topology shows an adequate performance for tracking of reference voltage with smallripples that are normally reflected into smaller EMI noise. Moreover, it has been shown that the operationof the DC motor with the newly proposed chopper topology to implement rotational and speed control system for DC motor based electric vehicles.The simulation results are provided to validate the proposed chopper technology.

INTRODUCTIONNowadays, Direct Current (DC) motors are the main horsepower of the most of the industrial process operations. Thesemotors find a wide area of applications such as roboticmotions, automatic manipulations, electric and hybrid vehicles,traction system, servo systems, rolling mills, and similarapplications that require adequate process. The DC motorsand their associate control and drive system are classified as the first choice compared to the available AlternatingCurrent (AC) motors and their drive systems. The DC motoracquires this popularity due to many merits such as simplicityof its control and drive system compared to AC counterpart,linear variation of the torque and speed against appliedarmature voltage, wide controlled speed and wide controlledtorque ranges, compact of size with high power efficiencyfor Permanent Magnet DC (PMDC) motors, and finally the overall low cost.To control the DC motor rotor position, rotor speed, or the developed torque, the motor field current or the armature voltage is controlled to achieve the control goal. The armature terminal voltage through power electronic circuits is mostlyused in the motor control system especially for the relatively high-power machines. In a modern industrial situation, DC motor is widely used which is due to the low initial cost, excellent drive performance, low maintenance and the noise limit. As the electronic technology develops rapidly, its provide a wide scope of applications of high performance DC motor drives in areas such as rolling mills, electric vehicle tractions, electric trains, electric bicycles, guided vehicles, robotic manipulators, and home electrical appliances. DC motors have some control capabilities, which means that speed, torque and even direction of rotation can be

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changed at any time to meet new condition. DC motors also can provide a high starting torque at low speed and itis possible toobtainspeedcontrolover a wide range.

PROPOSEDCONVERTERThe proposed block diagram of the multilevel chopper circuit(MLCC) for a DC motor drive system .

is shown in Fig. 1.This suggested system consists of the proposed MLCC block,H-bridge block in order to control the direction of the motorrotation, PMDC motor, in addition to many control blocksthat arrange and synchronize the operation of the whole system

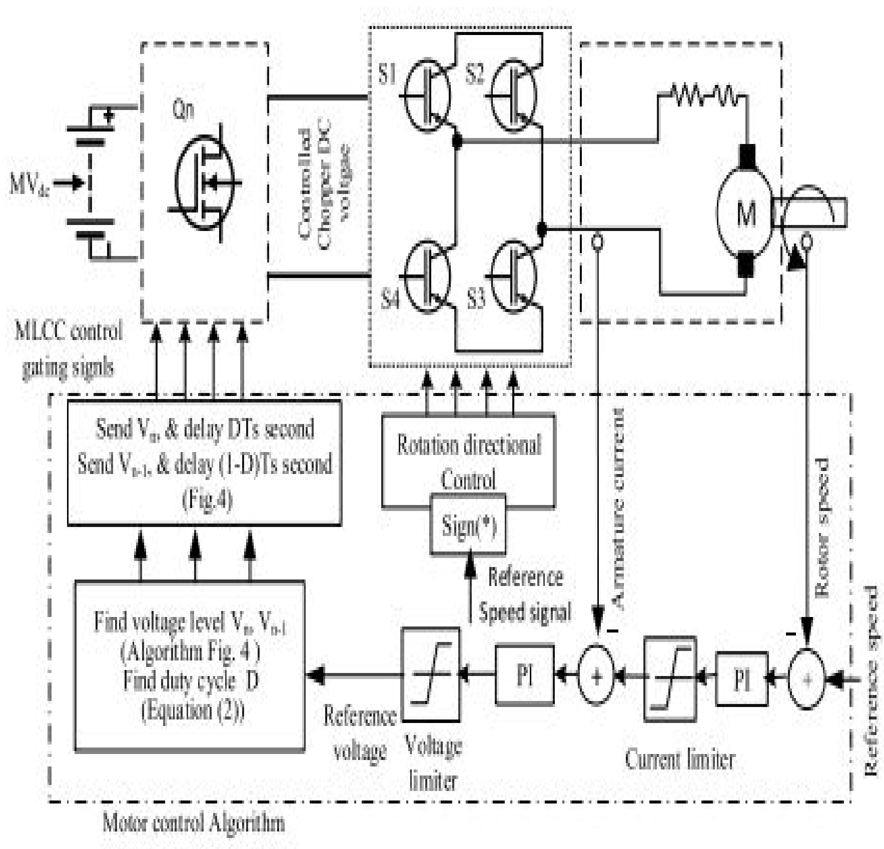

Figure 1. Block diagram of DC motor drive with MCC

In this research work, the suggested multilevel choppercircuit (MLCC) is a 5-level power converter as illustratedin Fig. 2, it is composed of four controllable power switchessuch as power MOSFET. The MLCC consists of threeclamped diodes, (D1, D2 D3), preferably Schottky diodes andfreewheeling diode DF: These diodes together with the powerswitches actualize the correct operation of the multilevelchopper circuit.The voltage of the sources VDC1, VDC2, VDC3 and VDC4are of equal or different voltage values. These independentDC voltage sources could be cell storage batteries, solar cellunits or any equivalent DC voltage sources.

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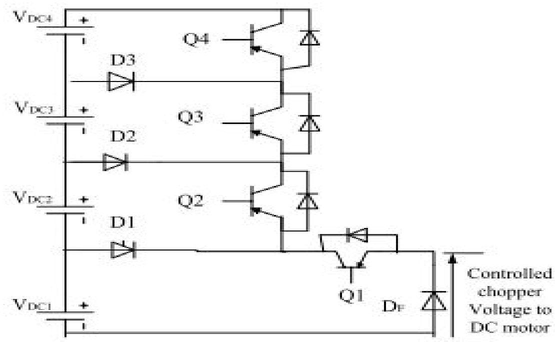

Figure 2. Configuration of 5-level diode clamped multilevel chopper circuit

PRINCIPE OF OPERATION OF MLCC CONFIGURATION

One typical application of the proposed MLCC is in the field of electrical vehicles that are mostly operated by DC motors. These types of vehicles work in an open control mode, where the applied voltage level to the armature of the DC motor determines the vehicle speed (or the driving torque). The voltage source, in such vehicles, is composed of 4 batteries (each of 12 volts connected in series), which provide typical voltage requirements for the proposed MLCC. Thus, the performance of the proposed MLCC is simulated with such a typical PMDC motor. To accurately evaluate the proposed topology, the MLCC is simulated in closed loop control mode. The simulated circuit is arranged as given in Fig.1.

A P.I Controller is a feedback control loop that calculates an error signal by taking the difference between the output of a system. The controller receives a current and voltage measurement which it then uses to calculate the power being drained from the battery. Once the power is measured the error signal is calculated by taking the difference between the set point and the power measured. The error signal then goes into the P.I control loop where it gets multiplied by the proportional and integral constant. The output of the P.I control is a power value and in order to convert it to a quantity that is comparable to that of the control signal, it goes through a power to PWM signal converter.The Pulse-Width-Modulation (PWM) in microcontroller is used to control duty cycle of DC motor drive. PWM is an entirely different approach to controlling the speed of a DC motor. Power is supplied to the motor in square wave of constant voltage but varying pulse-width or duty cycle. Duty cycle refers to the percentage of one cycle during which duty cycle of a continuous train of pulses.

$$e(t) = SP - PV$$

$$u(t) = u_{bias} + K_c\, e(t) + \frac{K_c}{\tau_I} \int_0^t e(t) dt$$

$$u(t) = u_{bias} + K_c\, e(t) + \frac{K_c}{\tau_I} \sum_{i=1}^{n_t} e_i(t) \Delta t$$

The u_{bias}term is a constant that is typically set to the value of u(t) when the controller is first switched from manual to automatic mode. This gives "bumpless" transfer if the error is zero when the controller is turned on. Digital controllers are implemented with discrete sampling periods and a discrete form of the PI equation is needed to

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approximate the integral of the error. This modification replaces the continuous form of the integral with a summation of the error and uses Δt as the time between sampling instances and nt as the number of sampling instances.The controlled speed performance for the both methods are shown in figures 5 and 6 respectively. The proposed circuit configuration of multilevel converter controller is as shown in figure 3.

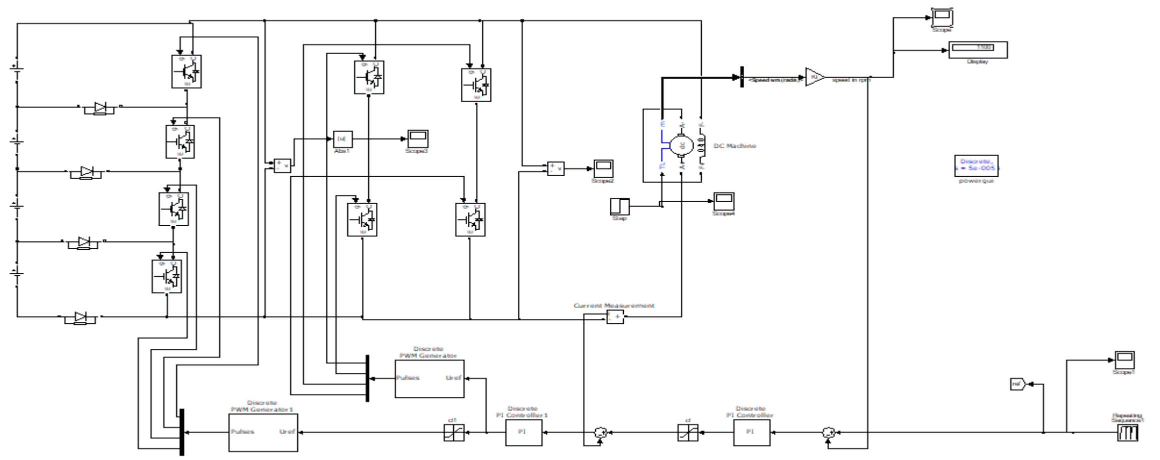

Figure 3. Proposed circuit configuration

The figure above shows a software level block diagram of the P.I control algorithm. The controller receives a current and voltage measurement which it then uses to calculate the power being drained from the battery. Once the power is measured the error signal is calculated by taking the difference between the set point and the power measured. The error signal then goes into the P.I control loop where it gets multiplied by the proportional and integral constant. The output of the P.I control is a power value and in order to convert it to a quantity that is comparable to that of the control signal, it goes through a power to PWM signal converter. The adjusted PWM signal (output of PWM converter) then gets compared with the throttle signal, which is also a PWM signal, that is being sent by pilot, the least of the two gets sent to the controlled system. The controlled system block encompasses the battery, motor, speed controller, and limiter.

Controller design for any system needs knowledge about system behavior. The MATLAB/SIMULINK software package can be advantageously used to simulate power converters. Suppose that a driver of a vehicle set the desired speed set point to a value higher than the maximum speed. The automatic controller would saturate at full throttle and stay there untilthe driver lowered the set point. Suppose that the driver kept the speed set point higher than the maximum velocity of the vehicle for an hour. The discrepancy between the set point and the current speed would create a large integral term. If the driver then set the speed set point to zero, the controller would wait to lower the throttle until the negative error cancels out the positive error from the hour of driving. The automobile would not slow

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down but continue at full throttle for an extended period of time. This undesirable behavior is fixed by implementing anti-reset windup. The corresponding waveforms for an electric vehicle moving with constant speed and with variable speeds for an instant of time are shown in figure 5 and 6 respectively.

From the above figure, the driver wants to run the vehicle motor with the speed of 1000 rpm within one second and suddenly drops to 900 rpm runs up to three seconds and again run the motor after three seconds with 1200 rpm again drops to 1100 rpm and runs up to 10 seconds. This is the task performed by the driver. To withstand this kind of larger variations within shorter time periods we want to develop this type of advanced drive circuit. This MLCC motor drive will be adoptable for any kind of electric vehicle and faster in response.

The simulation results of DC motor drive circuit using multilevel chopper circuit are given below figures 5 and 6.

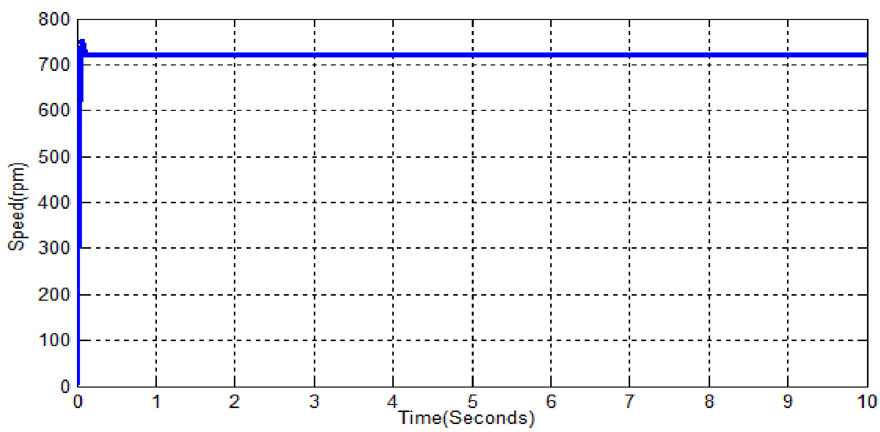

Figure 4. Speed vs Time characteristics for constant speed mode

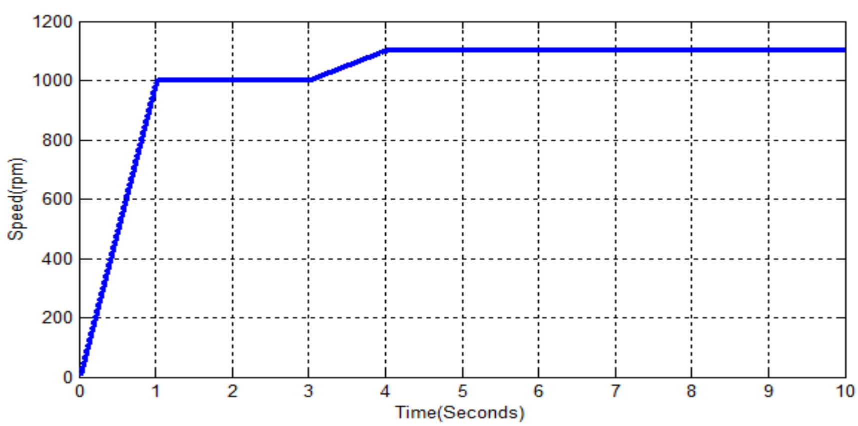

Figure 5. Speed vs Time characteristics for variable speed mode

From the above figure, the driver wants to run the vehicle motor with the speed of 1000 rpm within one second and suddenly drops to 900 rpm runs up to three seconds and again run the motor after three seconds with 1200 rpm again drops to 1100 rpm and runs up to 10 seconds. This is the task performed by the driver. To withstand this kind of larger variations within shorter time periods we want to develop this type of advanced drive circuit. This MLCC motor drive will be adoptable for any kind of electric vehicle and faster in response.

CONCLUSIONThis projectpresentssimulation resultsof a new topology of the multilevel chopper DC/DCconverter for a DC motor system. The main objective ofthe propounded topology is to implement both rotational and speed control system for DC motor based electric vehicles. Electric vehicles are the trending topic in electrical engineering. So, electric vehicles must have the ability to withstand for four quadrant operation and dynamic speeds suppose in case of car parking the vehicle have the ability to move forward and backward according to the situation. current ripples andtorque ripples that are associated with hard switching ofthe traditional chopper circuit. The generated voltage pattern of thistopology has relatively smaller switching ripples comparedto the traditional step-down DC/DC power converters. It hasbeen shown that the operation of the DC motor with the newproposed chopper topology can efficiently control the speed and also the rotation of the DC motor based electric vehicle.

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