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Modular Multilevel DC-DC Converters In Hybrid Electric Vehicle

Jyothi.V[1], Anitha.P[2]

[1] *Student, Electrical and Electronics, Adi Shankara Institute of Engg. And Technology, Kerala, India,*
[2]*Assistant Professor, Electrical and Electronics, Adi Shankara Institute of Engg. And technology, Kerala, India,*

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Abstract: *By having an eye on present scenario of our earth, it has been seen that global warming has been increasing dangerously and it affects our environment in hazardous ways. The major reason for the same is due to the blind dependency on non-renewable energy sources. Hybrid electric vehicle are one of the most practical usable system which will reduce the dependency on diesel and petrol, which are major non renewable resources. So here we are going to discuss the best converter suitable for HEV and conduct experiment of the same.*

Key Words: DC-DC Converter, modular multilevel converter (MMDC), high power applications, hybrid electric vehicle (HEV).

1. INTRODUCTION.

The usage of vehicles is increasing day by day. As the vehicles are fed by fossil fuels such as petrol and diesel which cause air pollution leading to global warming and related issues. More over fossil fuels are no longer a reliable source of energy as they are fastly exhausting. So here comes the role of hybrid electric vehicles which use less amount of fuel consumption compared to conventional vehicles [16][17].

Hybrid electric vehicle consist of a conventional IC engine and an electric motor part. For the electric part we make use of a converter, electric motor and a battery. Both the IC engine and electric motor can be used alternatively and hence it can reduce the dependency on fuel. Electric motor can be charged from and electric supply. Dependency on electricity which is produced from renewable resources are much advantageous than non renewable energy sources. This shows the importance of HEV.

So the main advantage of hybrid electric vehicle is that it reduces the dependency on fuel and environment impact. Simple block diagram of hybrid electric vehicle is given below.

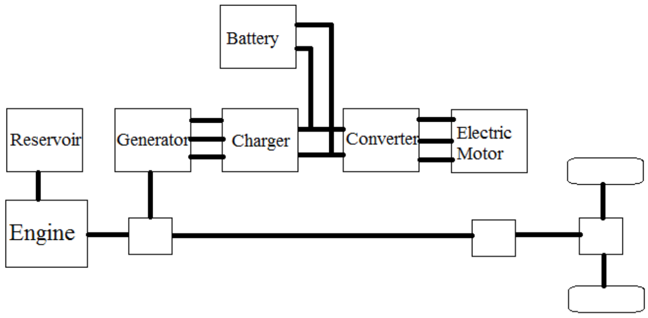

Fig 1: Block diagram of hybrid electric vehicle.

2. DC –DC CONVERTERS.

The dc-dc converter in hybrid vehicle is used to interface the elements in electric vehicle bt boosting or chopping the voltage levels. For the better efficiency if the system the power converter should be reliable, light weight, small volume. And then only the electric vehicle can achieve high performance.

The importance of using dc-dc converters in hybrid electric vehicles can be describes as given below:

- At least one dc/dc converter is necessary to interface the system.
- A bidirectional dc/dc converter is needed to make use of regenerative breaking.
- The power flow can be controlled by varying the duty ratio of the converter.

So as said before we should have a converter with properties such as light weight, high efficiency ,small volume, low electromagnetic interface, low ripple current, better power flow control etc.

3. PROPOSED SYSTEM.

In literature various converters such as buck, boost, buck-boost converters, interleaved converters etc are proposed for low power applications. In this paper a new topology is proposed which can be used in high power applications such as hybrid electric vehicles, hvdc systems etc.

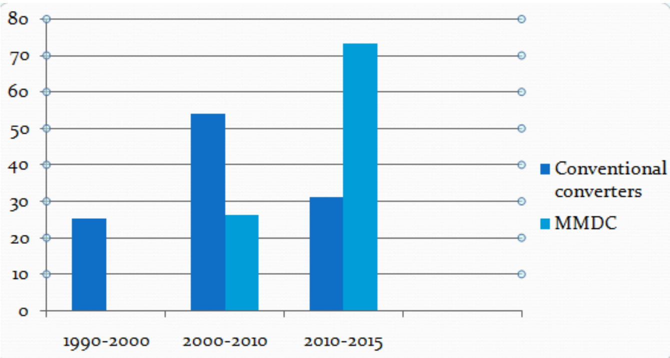

Chart -1: Graph which shows the researches taking place in conventional converter and MMDC on the basis of year

So this paper presents a new topology named modular multilevel DC-DC (MMDC) converters that can be used in high power applications. And from the literature survey it was identified tat more researches have been done in the field of modular multilevel DC-DC converters compared to other conventional converters.Chart-1 shows the comparative study of the researches carried out in field of conventional converters and MMDC.

The main feature of converter that can be used in electric vehicle is the property of bidirectional conversion so that it can make use of the regenerative braking. Some of the other features that are absent in the conventional converters are MMDC is (i) Modular in nature. (ii)Transformer-less operation. (iii) Redundancy. (iv)Fault tolerant operation. (v) Fault bypassing capacity. (vi)Easy switching scheme. And also in the proposed system it is possible to transfer power from high voltage battery to low voltage battery and vice versa, the direction of power flow depends upon the voltages at the both end.

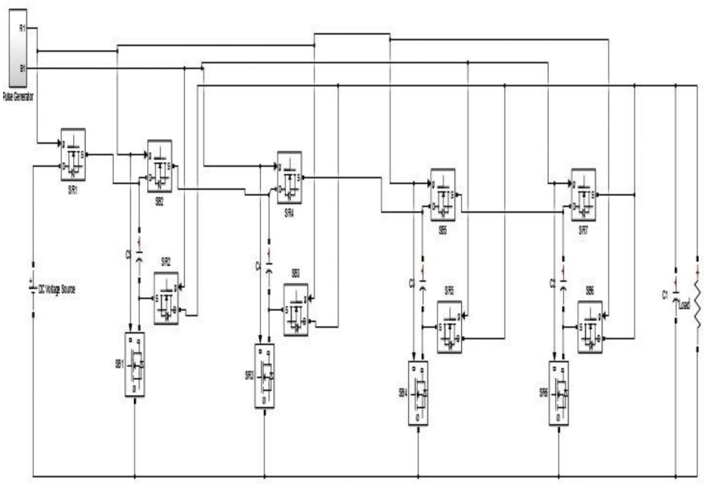

Fig -1:Five Level Modular Multilevel Dc-Dc Converter.

The new converter topology is modular in nature. A module consists of 2 mosfets and 1 capacitor. If N is the number of levels that is to be obtained then number of modules is equal to (N-1).The main advantage of this new topology is that regardless of the number of levels only 2 operating states is needed. Mosfets (SR1-SR7) operate together and Mosfets (SB1-SB6) operate simultaneously. As the switching is simple, the operation will be speedy. From the steady state analysis it was obtained that the values of each capacitors used in each modules are same in value.

To obtain the switching scheme, it is initially assumed that the converter will perform its operation in 5 operations or 5 sub intervals which is based on the charging of capacitors. In first subinterval C5 is charged from the battery source and discharges through output circuit. In second subinterval C5 transfer its charge to C4 through the output circuit. In the third subinterval C4 released its charge to C3 through output circuit and at the same time C5 gets charges through input circuit. In the fourth subinterval in addition to C3 transfers charge to C2 through output circuit, second subinterval operation also takes place. In fifth subinterval,3 operations take place ie C5 is again charged from the input circuit,C4 transfers its energy to C3 and also C2 transfers its energy to output circuit. The last two subintervals are repeated again and again and the two operations and taken as state 1 and state 2 operations. Last two operations are the steady state operations and the rest are considered as the initialization step.

So the switching scheme for this operation can be obtained easily. The operation of SR1-SR7 is considered as the state 1 operation and the operation of SB1-SB6 is considered as the state 2 operation. This is much more simplex than the conventional converters. Fault by passing capacity is very good as it is easily possible to eliminate the faulted module. And also it can increase its number of levels by just increasing its number of blocks. Due to so many advantages it is very much advantageous to use in high power applications.

3. MODELLING OF HYBRID ELECTRIC VEHICLE.

A typical HEV consist of an IC engine, a power splitter, synchronous generator, synchronous motor, rechargeable battery and a power management system.

The IC engine is directly connected to the carrier of the planetary gear which splits the mechanical power to the generator. The power management system is the brain of hybrid electric vehicle which controls the HEV working in different modes. It is also used to control motor speed or torque. The battery provides the power at lower speeds or assists the engine during sudden acceleration. It also acts as generating mode during deceleration which recovers the kinetic energy as electrical energy.

3.1 Synchronous Motor/Generator.

Even through various modes of generators are available, all of them take the detailed physics into account. Here the most important application for generator is that the output frequency is determined by input shaft speed and amplitude of output can be controlled.

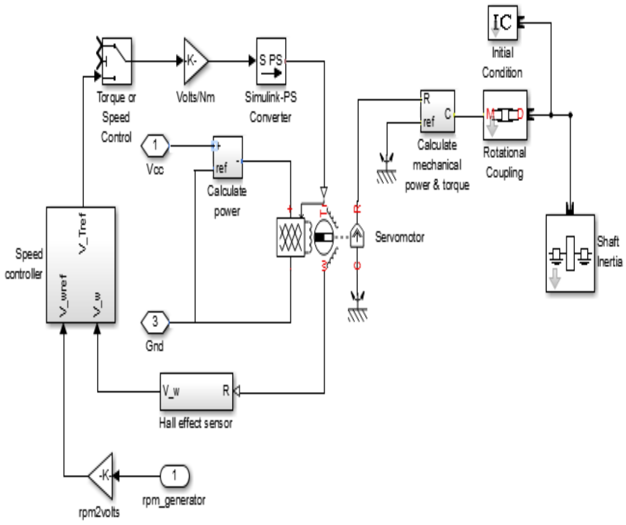

Fig -2:Synchronous Generator Modeling System.

3.2 Power Management System.

The entire control algorithm for the hybrid electric vehicle is controlled by power management system. Speed control, Torque control, Battery charge control, Over-current protection, Under-voltage protection are some of the main functions of the power management systems.

The speed control and battery charge control of the system can be shown as:

Engine speed controller is used for the demands below the idle speed of 800 rpm the speed demand is set to zero. The limiter in the battery charger is used because If the battery has more than required ampere hour, then no generation is required. Linearly ramp to using 20% of engine torque for charging between the ranges needed

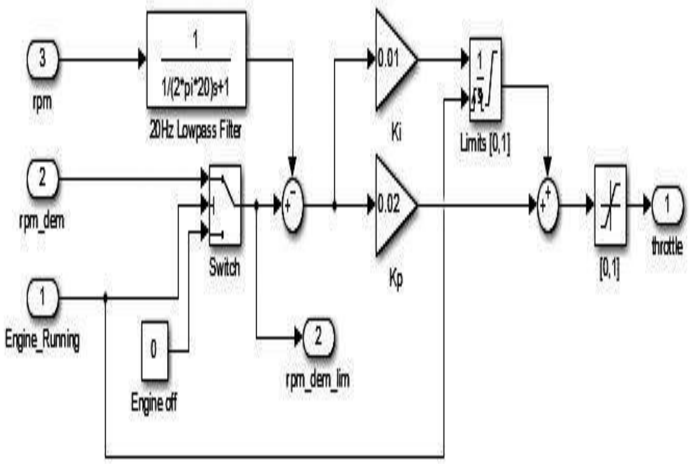

Fig -3:Speed Controlling System

The battery control for the system is given by:

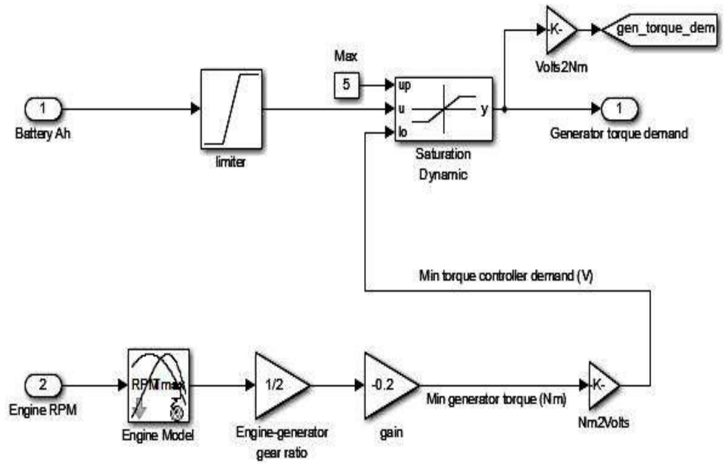

Fig -4:Battery Control System.

The control system of the drive calculates from the flux and torque references given by the drive's speed control the corresponding current component references. Typically proportional-integral (PI) controllers are used to keep the measured current components at their reference values.

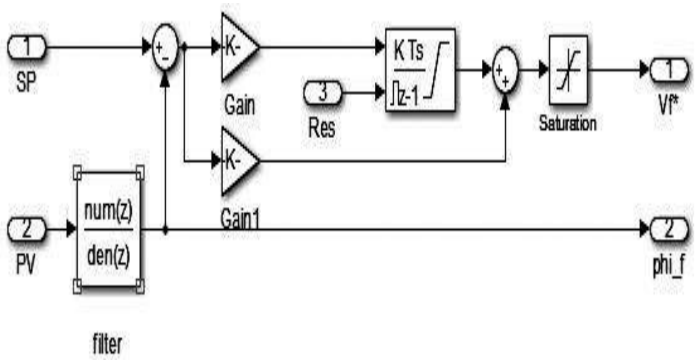

Fig -5 :Vector Flux Control.

4. SIMULATION RESULT.

After simulation of the MMDC converter alone, it is then simulated with hybrid electric vehicle with various control such as speed control, torque control, vector control, and also the main important part i.e. the power management system. The converter side and the vehicle side are interfaced with the help of converter which converters the dc output from MMDC to an AC input to the vehicle side.

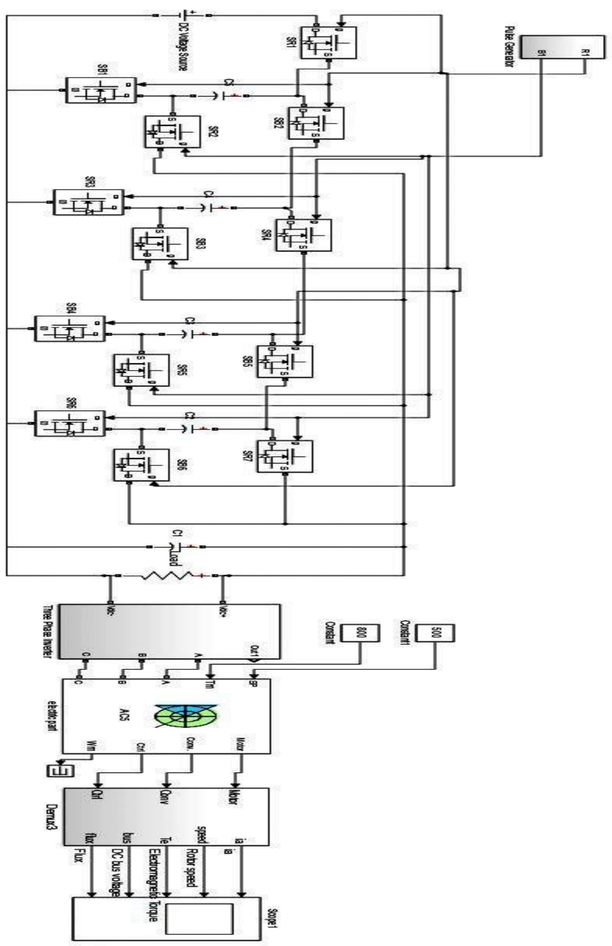

Fig -6 :Five level MMDC with HEV

From the experiment done the obtained result was as given below.

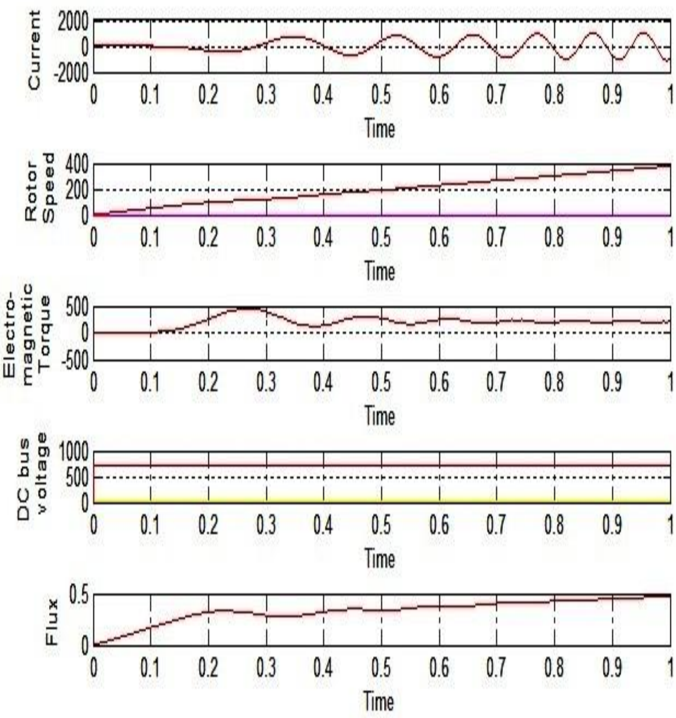

Fig -7: Output Waveforms.

Current, Rotor Speed, Electromagnetic Torque, Dc bus Voltage, Flux of the vehicle is are plotted and the graphs shows the proper working of the system.

5. CONCLUSION.

The proposed new topology is modular in nature. As it is modular the fault bypassing capacity is good. If any fault was identified in the system that module can be easily removed or bypassed so that other modules can work properly. Due to the same valued capacitors used in MMDC, the voltage stress across the switches is reduced and hence the ripple voltage and current will get reduced. So we can conclude that the converter is modular, have high frequency operation, bidirectional power management, fault bypassing and due to the absence of inductor in circuit the harmonics will be less.hus the converter can be used in various applications to establish bidirectional power management such as in hybrid electric vehicles.

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BIOGRAPHIES

Jyothi.V was born in Kerala, India in 1991.She received her B.Tech in Electrical and Electronics Engineering in 2013 from NSS college of Engineering, Palakkad, Kerala.. She is currently pursuing Master of Technology in Power Electronics and Power System from Adi Shankara Institute of Engineering and Technology, Cochin. Her current research interests include Power Electronics and Renewable energy systems.

Anitha P was born in Kerala in 1969. She graduated from M A college of engineering in Electrical& Electronics Engineering in the year 1991.She took her M Tech in Industrial drives & control from Rajagiri School of Engineering & Technology under M G university She is working as Asst. Professor in the department of Electrical & Electronics Enginering at Adi Shankara Institute of Engineering & Technology Kalady from 2001.

