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Electrical Power Generation and Storage System in Electric Vehicle–An overview

A. Geetha*, C. Subramani*, T. Thamizh Thentral* and Tarana Parvez Kaovasia*

ABSTRACT

This paper is to present an overview of the state of the art in electrical power generation and storage systems in today's automobiles. Automobile systems are safety critical and they are required to be highly fault tolerant in operation. Almost all the automotive systems comprises of mechanical, hydraulic, software and hardware components. In addition there is an enough embedded electronic control units (ECU) within the systems to provide convenience and safety features to vehicle drivers, passengers and public and objects such as pedestrians and other vehicle. Proper operations of these components completely rely on electric power. The detection of faults in such electrical systems and the prediction of the remaining useful life of the failing components are very critical. Thus the monitoring of the state of health (SOH) of the automotive Electrical Power Generation and Storage (EPGS) systems play a vital role in current automotive. An accurate diagnosis of faults in it provides a reliable electric power supply to the vehicle and thus offers the person safety and reduction in vehicle maintenance cost. There has been a lot of research on diagnosis or health monitoring of the energy storage system (battery) but very little work on the diagnostics of the automotive power generation system (alternator) in the past years.

1. INTRODUCTION

Increased complexity and criticality of electrical system of modern day vehicles has resulted in a paradigm shift in the manner used to monitor, maintain and repair critical equipment and processes on board ground vehicles. Instead of the traditional breakdown or scheduled maintenance, on line key condition indicators are monitored and equipment is maintained on the basis of their condition only. These condition indicators can assist to detect, identify and predict the evolution in time of potentially detrimental fault conditions for a typical automotive electrical system [1].

The main purpose of the vehicle's EPGS system is to maintain the necessary electrical power needed to start the vehicle and keep it running smoothly. Figure 1 show the hierarchical structure of EPGS system. A healthy EPGS system is crucial for proper diagnostic of such EPGS is important for the vehicle owner and mechanic. Early diagnostics of a faulty EPGS system can warn the owner that the vehicle needs repair before more costly damage to other components occur [2,3]. But the current vehicle systems support the online diagnostic capabilities to quickly get to the root cause of any hazardous situation to understand whether it represents a failure or an emergent (but safe) condition and to adapt the system accordingly, all the while preserving safety, fault – tolerance and continuous operation.

Such online diagnostic procedures are completely unassisted by technicians without access to years' worth of field data and prior diagnostic experience. Building such self-diagnosing driving systems are a challenge indeed. Failure diagnosis goes beyond fault detection by providing extended information on the underlying cause of a system failure. Failure diagnosis is distinguished from fault detection in that detection aims mainly to determine that some fault occurred, while failure diagnosis might reveal what kind of fault occurred, what component(s) is/are responsible, and what caused the fault. Depending on the goals of the

* Department of Electrical and Electronics, SRM University, Kattakulathur, Chennai-603203, Tamil Nadu, India, *Emails: geeanbu@gmail.com, csmsrm@gmail.com, thamizhthentral.t@ktr.srmuniv.ac.in, taranakaovasia14@gmail.com*

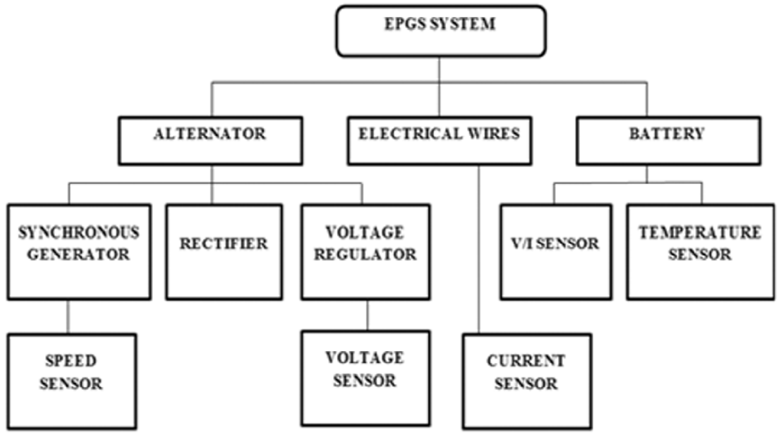


Figure 1: Hierarchical Structure of EPGS system

specific failure diagnosis strategy, this extended information could be useful to engineers during design, integration and testing; technicians during service; and at runtime to allow for more robust failure mitigation mechanisms[4, 5].

The need for failure diagnosis can be seen from two perspectives: a maintenance-oriented perspective and a safety-oriented perspective. The maintenance-oriented perspective is concerned with improving diagnosis to aid service personnel and reduces warranty costs often with the vehicle in an offline mode. The safety-oriented perspective is concerned with supporting the overall dependability of safety-critical systems typically for the vehicle in an online mode.

2. AUTOMOTIVE EPGS SYSTEM

The major component of an automotive EPGS system includes the alternator, the battery, the drive belt and the controller. Figure 2 and 3 show the complete circuit of an EPGS system.

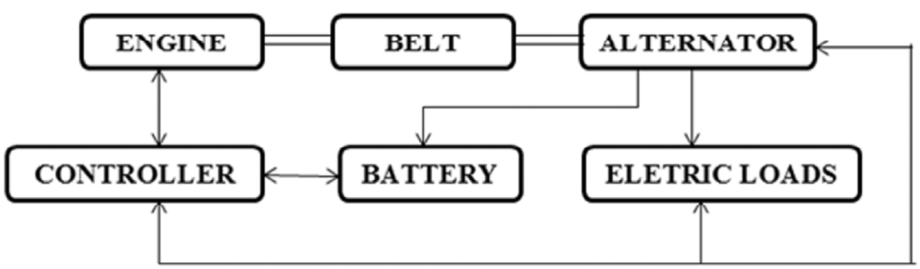


Figure 2: Block diagram of an EPGS system

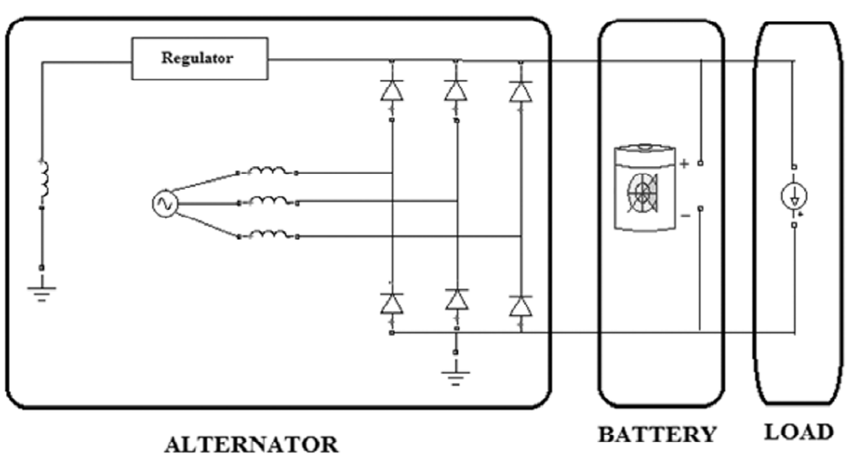


Figure 3: Complete internal circuit of an EPGS system

3. ALTERNATOR

The current demands made by modern vehicles are considerable. The generating system must be able to meet these demands under all operating conditions and still 'fast charge' the battery. The main components of a generating system are the alternator, a three phase diode bridge rectifier, regulator to control the alternator output voltage and excitation field. The major functions of this generating system are that they supply the current demands made by all loads.in addition to that it supplies whatever charge current, the battery demands, supply constant voltage under all conditions, have an efficient power to weight ratio, be reliable, quiet and have resistance to contamination, require low maintenance.

Usually Lundell or Claw pole alternator is used as shown in figure 4. It is a three phase field wound synchronous generator with three phase diode bride rectifier [10-12]

3.1. Merits of Alternator Over DC Generator

In current trend, vehicles are equipped with many electrical units which lead to increased DC which in turn increases the size, weight and speed of the DC generator. But this may be difficult due to the limitations in the brush and commutator units present in it. This has provided a way to employ alternators or alternating current generators. The merits of alternator over the generators are that an alternator can run safely at about 2.5 times the engine speed whereas for a DC generator is limited to about 1.75 times the engine speed.

A well designed alternator can run at 20000 rpm (or) more but the drive ration of a alternator is limited to around 2.8:1 due to the limitation in belt and pulley size limitations. An alternator has high output-weight ratio. The output of an alternator with separate rectifier is 50% greater than that of DC generator, whereas the inbuilt rectifier-alternator unit can produce output more than 100% of DC generator.

An alternator requires less maintenance since it uses light weight slip ring brushes whereas in the case of DC generator, it uses heavy brush gear and commutator.An alternator has more reliable operation than DC generator since it is simple and robust.Even for low engine speeds, a high output can be obtained in alternator, but that is not a case in DC generator.The rectifier in alternator does not allow any reverse current to flow from battery when the alternator voltage falls below the battery voltage.An alternator can offers a good self-regulation due to its winding reactance which avoids the use of external control.

However there is an increased initial cost in an alternator due to the inbuilt rectifiers, the distinct advantages of an alternator as listed above gains more popularity in the modern vehicles [13-17].

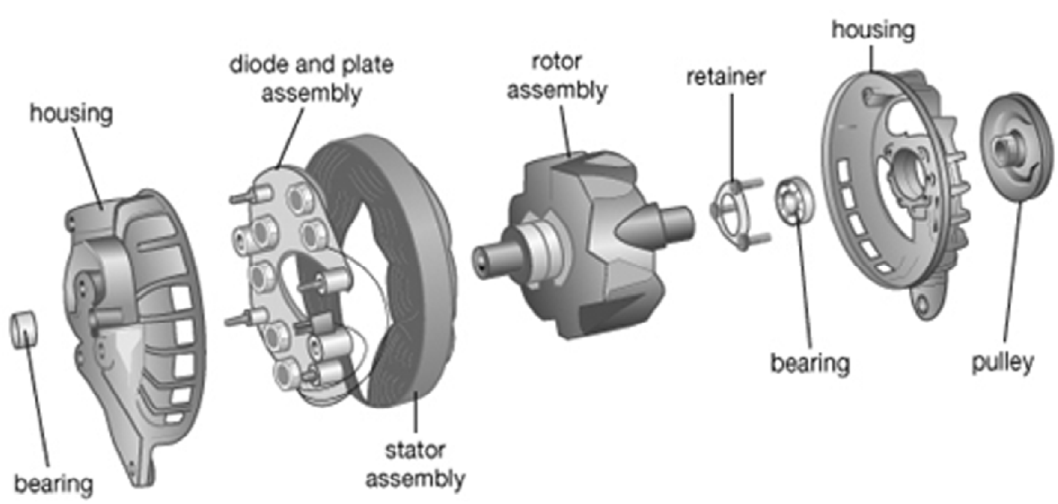


Figure 4:Claw pole alternator

4. BATTERY

The battery is an electrochemical device that converts electrical energy into chemical energy during charging and converts chemical to electrical energy during discharging. The major functions of battery in an automotive system is that when the engine is off, the battery provides energy to operate lighting and other electrical accessories. When the engine is starting, the battery provides energy to operate the starter motor and ignition system. While the engine is running, the battery energy may be needed when the vehicles electrical load requirements exceed the supply from the charging system.In addition, it also serves as a voltage stabilizer by absorbing abnormal, transient voltages in the vehicles electrical system [18-20].Better operations of batteries rely on its management system. State of charge (SOC) of batteries is the most important role player among many other important parameters of it. It is impossible to measure the SOC directly. Chemical composition of battery is a primary consideration for SOC estimation. Thus modelling of battery cell plays a major role in estimating the accurate value of SOC [21]. Overcharging and over discharging of batteries exhibits high damages in each cell. Those damages must be prevented in advance to increase its life time. Hence optimization algorithms must be used and it must incorporate battery current and terminal voltage [22].

4.1. Internal resistance model

The significance of internal resistance model is to describe the battery capacity in terms of open circuit voltage (OCV). Here, battery ohmic resistance is indicated by Ro. Figure 5 shows the equivalent circuit of internal resistance model of battery

4.2. RC model

In RC model, Cn indicates nominal capacitance and Voc(SOC) represents open circuit voltage as a function of SOC. Current discharge due to the effect of electrode material is denoted as Cd and Vcs is the surface

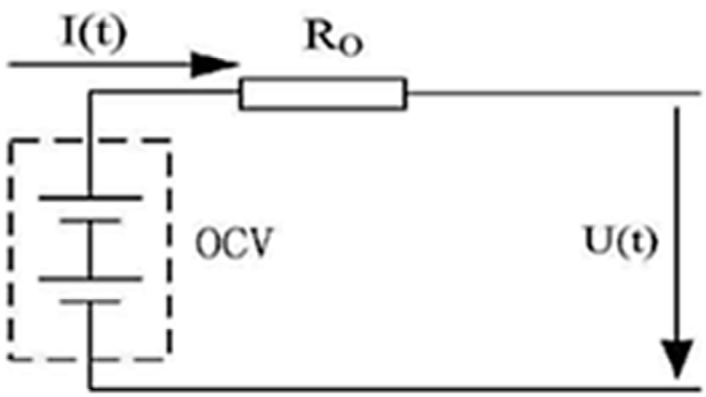


Figure 5: Battery internal resistance model

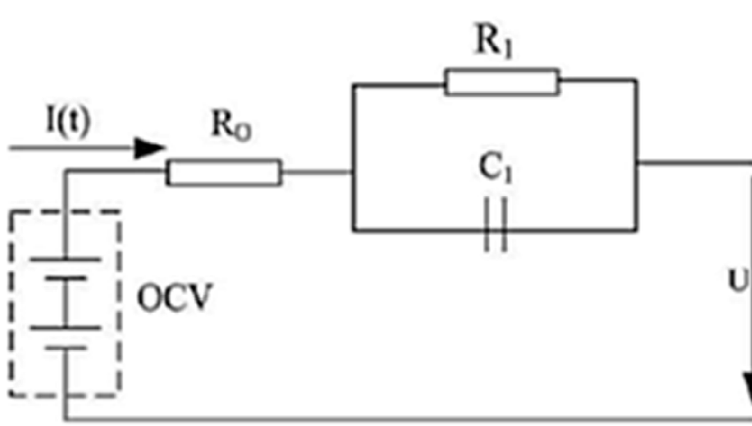


Figure 6: Battery RC model

capacitor voltage. End, surface and terminal resistance are represented as Re, Rs and Rt respectively. Negative indication of current represents the discharging current. Figure 6 shows the Battery RC model.

4.3. Thevenin battery model

OCV is the voltage across Cn which helps in SOC estimation. Electrochemical polarization capacitance of the model and its corresponding resistance is denoted as CpamdRp. Ri is the input ohmicresistance[23-25]. Figure 7 represents the thevenin's equivalent model of a battery.

5. DRIVE BELT

Belt looseness failure mode will increase the belt slip as well as the wear progress of the transmission system. The major reason for this is tension loss that this caused by the varying distance between load and motor. At last it may lead to pulley grooves damage, belts breakage and critical slip. By rotating the rotor of the alternator, the drive belt transfers the mechanical power from the engine to the alternator.

The drive belt must be properly tightened. An excessively tight belt causes rapid bearing wear. A loose belt causes belt slop, and reduces the efficiency of the energy transfer from the engine to the generator, which in turn reduces fuel economy [26-30].

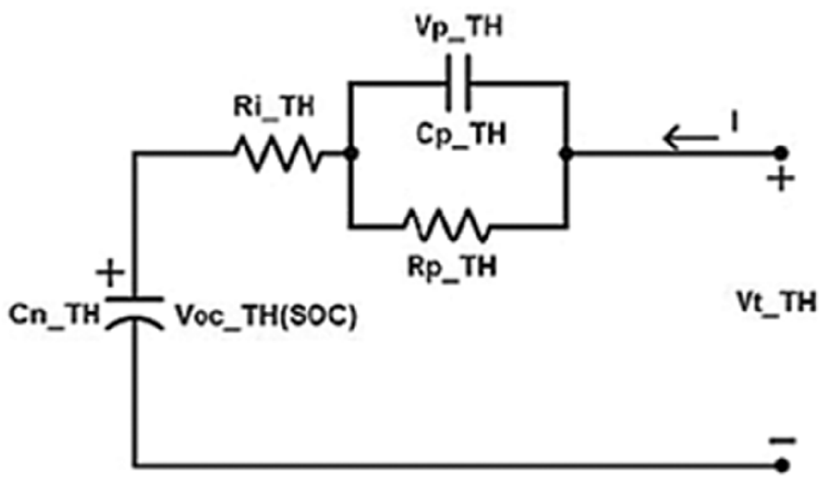


Figure 7: Thevenin battery model

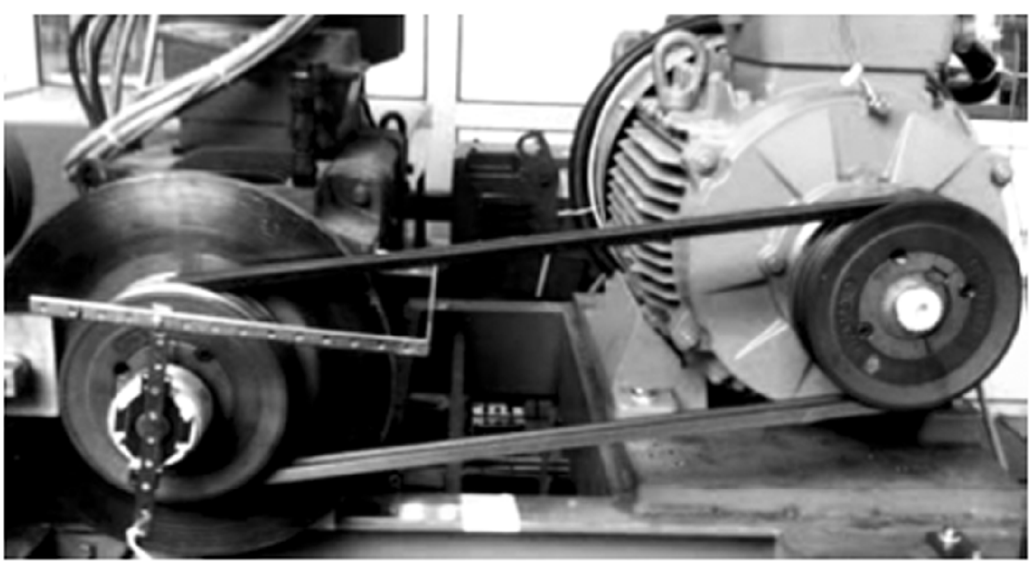
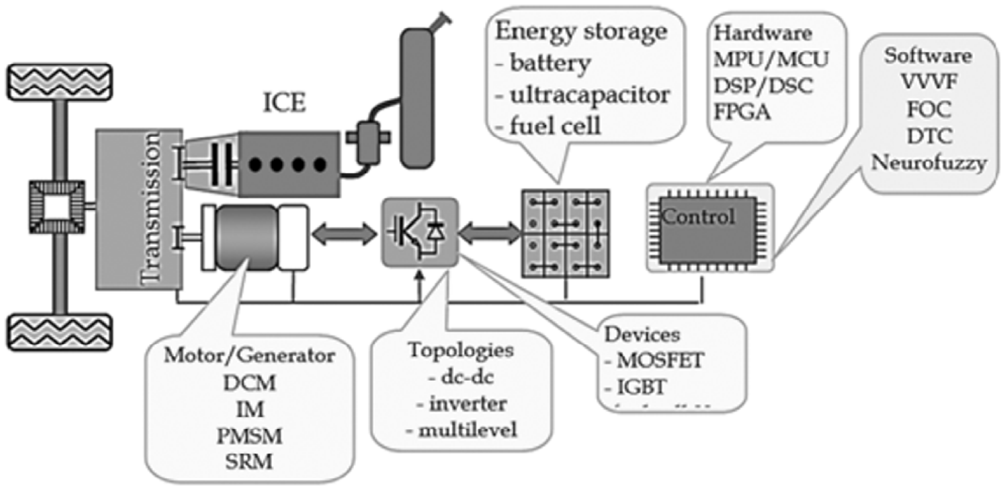


Figure 8: Drive Belt

6. VEHICLE CONTROLLER

Controllers on an automobile are usually called Electronic Control Units (ECU). The most critical thing in EV is to control the conversion of energy. Hence the design of controller plays a vital role in EVS. The Electronic Control Unit (ECU) acquires information from many sensors and assists several driving function. All types of information present in vehicle ECU must be broadcasted using CAN network.



The can bus acts as a main component used to communicate the control signals with in the vehicle. It implements the electrical power management strategy to provide optimal system controls. The main function of the electronic controller is to adjust control parameters for the smooth operation of the parts and select the optimum mode of operation under all driving conditions. ECU is used to adjust the output voltage of an alternator in relation with the battery's SOC so as to improve the fuel economy, battery life and generator efficiency [31-37].

7. CONCLUSION

Much recent advancement in modern vehicle depends on safe operation of Electrical power generation and storage system. Most of the electrical and electronics equipment like driver assistance systems are in need of reliable power supply. If any faults occurred the state of health of the EPGS is affected. It is necessary to monitor the EPGS system periodically. The correct diagnosis during faults will ensure a reliable electric power supply and reducing maintenance costs. Hence in this paper, a brief description of each component in EPGS is presented. A better diagnostic algorithm for the power system ensures the more efficient and rapid repair works.

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