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Design of Vehicle Cranking Counter System
Redefining Automotive SLI Battery Warranty

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Abstract:- In this paper, we present the design details of a vehicle cranking counter system device. In the current scenario battery companies give the warranty for automotive SLI battery on monthly basis. The main fatigue loading of the battery occurs during the cranking of the vehicle. The number of cranking/ignition cycles in commercial vehicles (taxis, mini trucks, buses, trucks, etc.) is significantly greater as compared with private vehicles. As a result, battery fatigue is much greater in the vehicles used for commercial applications. Thus commercial vehicle owners constitute a majority portion who claims for replacement of the batteries which are well within the warranty period. This leads to a total financial loss for the company to replace the batteries which are used heavily by this group of customers. Our project proposes the companies to give the warranty period in terms of the number of cranking completed by a vehicle, which is the major fatigue electrical load on an SLI battery during its lifetime. This would be achieved by integrating a low-cost cranking counter circuit inside the battery. By doing this the companies will incur fewer losses. The companies would be able to recognize the root cause of battery failure by analyzing the cranking data through the device.

Keywords:- *Vehicle Cranking, SLI battery (start light ignition), battery fatigue, commercial vehicles, private vehicles, warranty period, cranking data, DAQ: Data acquisition system.*

I. INTRODUCTION

The lead-acid battery has been in existence for more than 150 years, but the ubiquitous technology is still displaying remarkable traction. With a proven arrangement for reliable and low-cost energy storage, lead-acid battery plays an important role in our day-to-day life. An SLI battery is a lead-acid and rechargeable type of battery that is mainly used in automobiles. SLI means starting, lighting, and ignition; these processes are all consuming energy that is supplied by the vehicle's battery. A lead-acid battery is made up of a container, copper terminal, safety valve, and vent plugs on the external while positive and negative plates, sulfuric acid, and water on the internal. Batteries from different manufacturers may look different physically but these external parts are always the standard. What's more interesting to know are the internal parts. As it is a lead-acid battery, the plates are made up of lead and lead dioxide. A chemical reaction occurs when these plates are immersed into the sulfuric acid and water solution, thus producing the DC voltage of 12V or 6V which in turn powers up your vehicle's SLI system.

Currently the warranty of batteries used in the application of industry, solar and defense sectors is claimed on the basis number of charging and discharging cycles. They use a high-cost counter system that measures the charging and discharging cycles completed by a battery. But batteries used in the application of the automobile sector still define the warranty terms in the number of months. Commercial utilization by some customers in this sector de-grade the overall performance within the warranty period and thus affecting the economy of the company. The study of 300 vehicles revealed that the average cranking for vehicles that were not used commercially was between 6 and 7 per day. Taxis had a considerably higher number of cranking, with an average and median of 24 to 26 cranking per day. This data signifies the need of using a counter system in vehicles for measuring the number of cranking completed. New warranty terms and conditions could be introduced based on the number of cranking(s) completed with the normal monthly warranty terms.

II. LITERATURE REVIEW

A. Battery warranty status

Currently, the warranty of the SLI batteries is given in terms of the number of months and the pro-rata period. When a customer comes to reclaim warranty of the battery, firstly the dealer checks for the physical damages and any external modifications. The voltage and Specific gravity of each cell are checked using multimeter and hydrometer. From multimeter data, cell voltages, undercharged/dead cells are identified. Then from the specific gravity data we come to know if the cells are dead due to overcharging. If overcharging is found as a reason, then the vehicle alternator is checked by the dealer. If the alternator is found to be defective, the warranty is rejected, otherwise, the claim is settled by giving warranty according to the pro-rata period.

In the existing warranty procedure and terms and conditions, there is no method to identify the customer usage pattern. This project aims at identifying the usage pattern of the customer based on the maximum fatigue electrical load on the battery, which is vehicle cranking. The warranty terms would be modified to the data from the customer usage pattern.

B. Starter motor and its effect on battery

An internal combustion engine requires the following criteria to start and continue running-The combustible mixture, compression stroke, a form of ignition, the minimum starting speed (about 100 rev/min). To produce the first three of these, the minimum starting speed must be achieved. This is where the electric starter comes in. The ability to reach this minimum speed is again dependent on several factors.

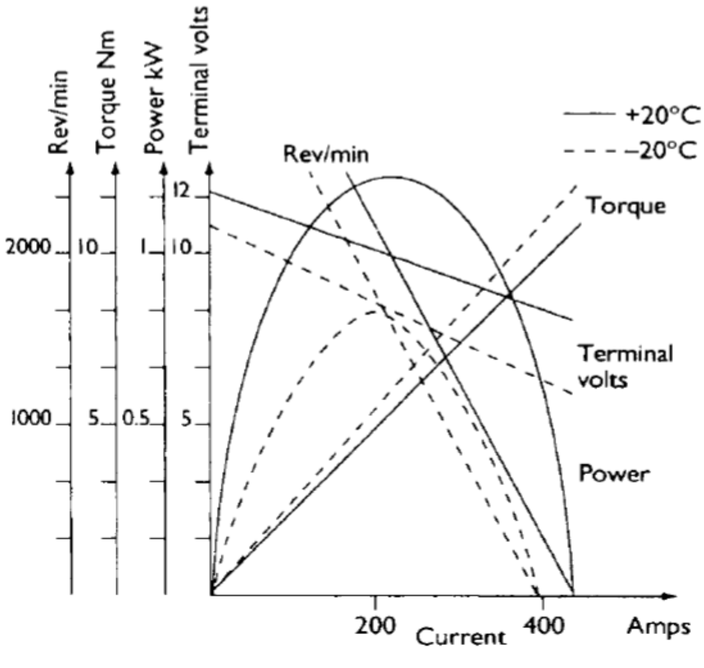

Fig 1:- Starter motor and battery characteristics(Automobile Electronics by Tom Delton)

Information on particular starters is provided in the form of characteristic curves. Figure 1 shows the details for a typical light vehicle starter motor. The graph tells that the current consumption of the starter motor can reach between 200 to 400 Amps. This can be classified as a fatigue electrical load on the battery. There is a voltage drop associated with such a high load which again increases the current drained through the battery.

Circuit (12V)	**Load**	**Cable drop (V)**	**Maximum drop (V)**
Lighting Circuit	<15W	0.1	0.6
Lighting circuit	>15W	0.3	0.6
Charging circuit	Nominal	0.5	0.5
Starter circuit	Max.at 20 °C	0.5	0.5
Starter solenoid	Pull-in	1.5	1.9
Other circuits	Nominal	0.5	1.5

Table 1:- Maximum Voltage Drop Data

The above table from the book “Automotive Electrical and Electronics Systems” by Tom Denton show typical maximum voltage drops of the vehicle battery due to various loads. The data shows that the voltage drop during cranking (starting) of a vehicle can reach up-to 1.9Volts.

C. Battery failure due to cranking

Engine cranking is a term used for the turning over or energizing the engine by some exterior force, normally a starter, but in the old days it was a "crank" that was turned by hand. It comes from the "crankshaft" which is the part of the engine that spins with the pistons and drives them to start and then is driven by them once the engine starts. To start the engine, a minimum starting speed must be achieved. The power to achieve this speed is supplied from the battery. The starter motor consumes power from the battery and rotates the engine crankshaft. As stated in the earlier section, the graph from fig 1.tells that the current consumption of the starter motor can reach between 200 to 400 Amps. This can be classified as a fatigue electrical load on the battery. Currently most of the SLI battery manufacturers are that claiming most battery failure is due to high cranking loads. This project will introduce a cranking counter device to identify the customer usage pattern.

III. METHODOLOGY

The cranking of the vehicle by starter motor is a major electrical load on the battery. The instantaneous voltage of the battery varies as the power requirements of the loads across it changes. The voltage drop for a particular load shows similar nature. The starter motor of a vehicle consumes maximum power than any other electrical component inside the vehicle. This results in a sudden voltage drop across the battery. This drop-in voltage is recovered as soon as the starting load is turned off. So, when the vehicles' engine starts the battery voltage is recovered and the battery starts to charge. Figure 2 shows this drop in voltage measured by a data acquisition system. Clearly this drop in voltage can be identified and measured with the help of a microcontroller by continuously monitoring the battery voltage. Fig 2 shows graphs of instantaneous voltage variation vs. sample number during cranking of the vehicle.

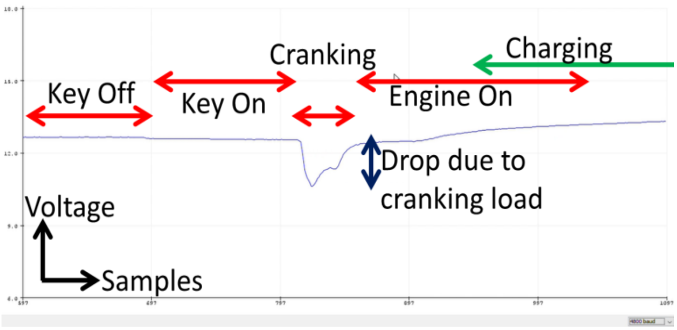

Fig 2:- The graph obtained by DAQ system showing voltage drop during vehicle cranking.

The voltage drop curve shows similar nature at various state of charge of the battery. Using a data acquisition system, the maximum and minimum limits of this voltage drop during vehicle cranking is measured at various state of charge of the battery. The acquired data is cultivated into an algorithm and program which could detect the cranking. A cranking counter device is manufactured which runs the cultivated program to detect the number of vehicle cranking (starts). The device is a small microcontroller that is securely fitted into the battery and connected in parallel. The cranking data acquired by the device can be retrieved at a later stage during battery warranty reclamation.

IV. EXPERIMENTS

A. Obtaining voltage variation data during vehicle cranking

This experiment for data acquisition (DAQ) is performed on two vehicles (two-wheelers moped type) Activa2g and Activa5g which use the starter motor for cranking. A DAQ consisting of a voltage sensor, recorder, graph generator and a microcontroller is used to record the instantaneous voltage data during cranking. The obtained graphs for voltage variation are shown in fig. 3 and 4.

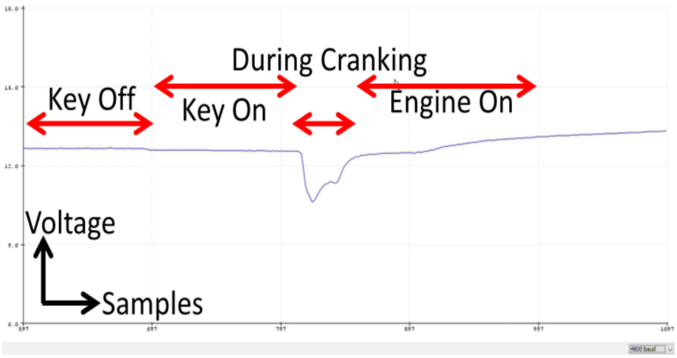

Fig 3:- Voltage variation during starting for Activa (2G model)

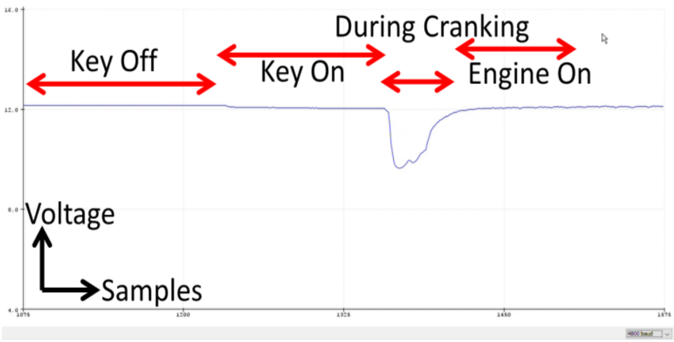

Fig 4:- Voltage variation during starting for Activa (5G model)

Such graphs and of voltage variation vs. samples taken are obtained at various SOC (state of charge) of the battery. Along with the graphs, accurate numerical data of instantaneous voltage variation is also obtained by the DAQ. Table 2 and 3 shows this selective and important data obtained during various phases of vehicle status and battery SOC for both vehicles. The data is obtained until 30% SOC after which the battery couldn't supply enough power for the vehicle to crank (start).

	VOLTAGE (VOLTS) 2G			
SOC (%)	***KEY OFF***	***KEY ON***	***DURING CRANKING***	***AFTER CRANKING***
100%	13.25	13.19	11.38	13.75
90%	13.1	12.92	11.12	13.22
80%	12.96	12.93	10.83	12.95
70%	12.81	12.52	10.91	12.77
60%	12.55	12.39	10.82	12.52
50%	12.39	12.24	10.3	12.42
40%	12.31	12.29	10.3	12.3
30%	12.15	12	9.1	11.94

Table 2:- Voltage and SOC for Activa2g

	VOLTAGE (VOLTS) 5G			
SOC (%)	***KEY OFF***	***KEY ON***	***DURING CRANKING***	***AFTER CRANKING***
100%	12.96	12.73	11.21	12.8
90%	12.84	12.71	11.19	12.7
80%	12.74	12.62	10.74	12.6
70%	12.56	12.47	10.48	12.54
60%	12.42	12.31	10.34	12.16
50%	12.24	12.18	9.88	12.16
40%	12.06	11.93	9.42	12
30%	11.87	11.73	8.44	12

Table 3:- Voltage and SOC for Activa 5g

This graphical data obtained are compared to verify the agreement between the data of the two similar vehicles. The graphs of voltage during various vehicle statuses (vehicle off, key on before ignition, during ignition, after ignition) vs. sample number are plotted for both the vehicles for comparison purposes. Below figures 5, 6, 7 show the voltage drop graph (due to cranking) comparison to verify the similar nature of drop which could be identified by programming a microcontroller.

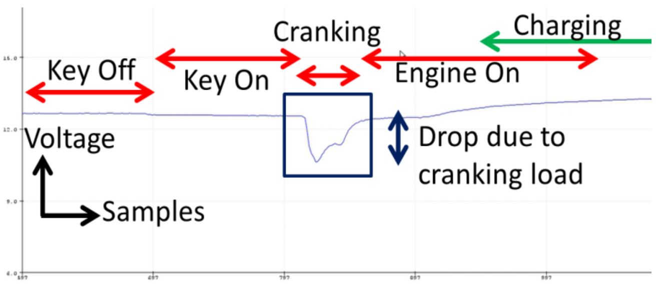

Fig 5:- Figure showing the location of the comparison window

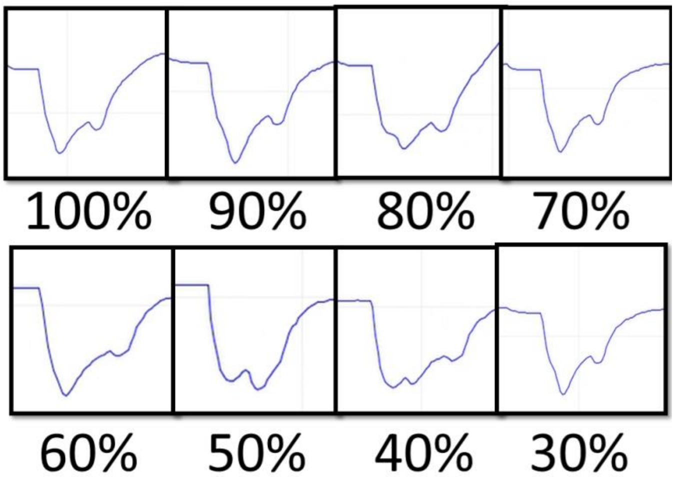

Fig 6:- Voltage drop at various SOC during cranking for Activa2G model

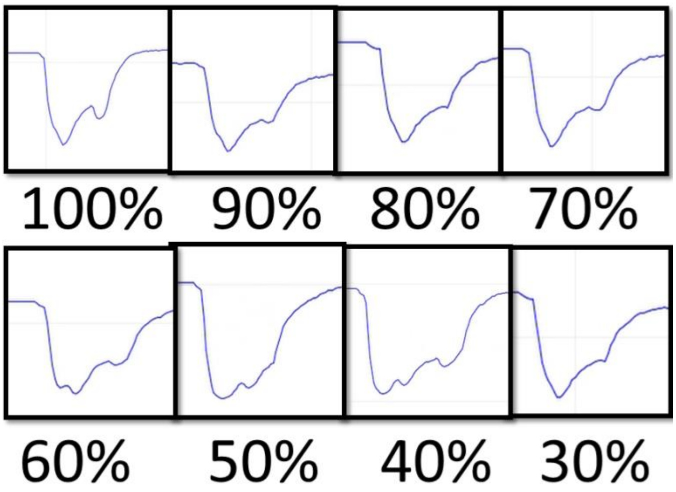

Fig 7:- Voltage drop at various SOC during cranking for Activa5G model

V. RESULTS

A. The conclusion from data acquired

From the graphs of cranking voltage drop plotted, it is concluded that-

- The pattern of the voltage variation during cranking at any state of charge of the battery remains similar irrespective of the vehicle model. This indicates that a common device (counter) can be designed to detect and count the number of cranking of the vehicle
- This data can be cultivated into an algorithm and program which could be used to detect the vehicle cranking
- A microcontroller could be programmed to accurately and precisely count the vehicle cranking and retrieve the data while warranty reclamation
- Battery warranty could be given in terms of number of cranking cycles

B. Device Design

A cranking counter device is designed, manufactured and tested on these two vehicles. Fig 8 shows the counter circuit diagram. The circuit consists of three parts-

- The counter device resides in the battery.
- The data retrieval device which the company uses to extract counting data from the batteries which come for warranty reclamation.
- The SLI battery itself.

The counter device is connected in parallel to the vehicle's battery and packed inside the battery while battery manufacture. The power for the microcontroller is extracted from the battery itself so there is no need for external power supply. The power consumption of the microcontroller remains negligible.

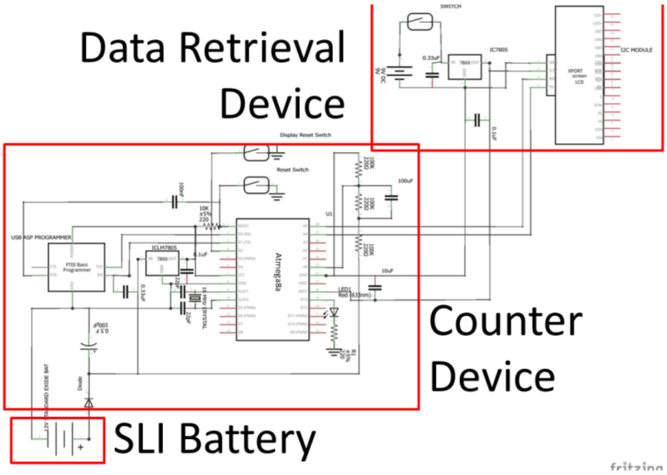

Fig 8:- Cranking counter device circuit schematic

The device uses an IC Atmega8A series low-cost microcontroller working on 5V logic. A 5V voltage regulator (LM7805) helps power the microcontroller through the vehicle's battery. The in-built ADC converter from the IC Atmega8A is used to sense the vehicle battery's instantaneous voltage through a voltage divider. The program logic which is into the microcontroller scans the voltage variation data to detect the cranking. There is also a provision of EEPROM memory (Electrically Erasable Programmable Read-Only Memory) into the microcontroller IC for data retention purposes in case the battery becomes dead and could not power up the device. The data can be retrieved at the company or dealership when the battery comes for warranty reclaim.

The technical details of the device components are shown in Table 4. Device components of the data retrieval device are listed in table 5.

Component	Specifications
Voltage Divider	50ohm×3
Atmel IC Atmega8A	8A (28pin)
Capacitors	(1nF*1,22pF*2,100nF*1)
Disc Capacitor	0.5uF
Circuit Board	Small
Regulator 5V	5V
Crystal	16MHz
Pins (Connector)	8 Qty.

Table 4:- Components of Counter Device

Component	Quantity
16*2 Digital Display	1
Reset Button	2
External 9V supply	1
I2C Communication Device	1
Circuit Board	1(small)
7805 Regulator 5V	1
Pins (Connector)	8 Qty.

Table 5:- Data Retrieval Components of Device

C. Programming Language

Arduino IDE is chosen for programming the Atmel IC Atmega8A series microcontroller. Arduino is an open-source language that eliminates the licensing issues and its platform provides abundant support. This is also the recommended language for coding the microprocessor. The algorithm and program prepared are suitable for counting ignitions of any vehicle using a starter motor. The program monitors the voltage variations of the battery and detects the ignition cycle through the algorithm. The program has the provision to send the counting data to the data retrieval device through I2C communication lines. I2C communication is selected due to its simple two-wire interface for data transfers. The acquired data is saved into the microcontroller memory. The program remains active through the life of the battery. It only detects, counts vehicle cranking and the use of battery for other power sources does not have any effect on the counts.

D. Device Compatibility

The cranking counter device can be used with any vehicle using a starter motor for starting purposes. This also means that it can be used with four-wheeler as well as two-wheeler vehicles (petrol and diesel) as long as they use starter motor. The programming remains the same for a particular vehicle model class. Only programming parameters need to be changed for different vehicle models while the logic and program remain the same for each vehicle. The device is equipped with the power conversion circuits so that it could be installed in batteries if any capacity. These features make this device suitable for universal usability.

VI. SUMMARY

According to the study of transportation research board, survey and data acquired by the company, frequent start, and restart of any vehicle degrades battery life and performance. Many commercial vehicles need frequent replacement of batteries.

Currently, the warranty is defined in terms of the number of months. We aim to replace existing warranty terms with the number of cranking a battery can sustain. The cranking counter device is used to identify and count the number of cranking. The battery manufacturer/dealer will have the power to access the counting data through the data retrieval device. Based on the counted data by the counter device, the warranty claim will be settled.

VII. CONCLUSION

- Frequent cranking deteriorates the performance and life of the battery. The maximum number of cranking in the commercial sector of the vehicle has a high frequency of warranty claims.
- DAQ setup which consists of a voltage sensor and microcontroller is used to determine the instantaneous voltage variation data of the battery and know the limits of voltage drop while cranking. This data is used to cultivate an algorithm and program for the microcontroller.
- Atmega IC 8A microcontroller is programmed to count the total number of cranking of a vehicle.
- The low cost and universal usability of the device make it profitable for the company.

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