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ENERGY AUDIT ON CAR ELECTRICAL CHARGING SYSTEM AT IDLE ENGINE

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ABSTRACT

In this paper, we present our work, which is doing an energy audit on alternator's current output and battery's voltage output at idle engine. Along with advances in technology today, the automotive industry has been growing rapidly and became competitiveness. One of the increasingly sophisticated fields is electrical charging system in the vehicle. Although as good as any of a carriage, it still requires the perceiver electrical system to move. Alternator and battery carriage mutual need between one another. Both of these things do work in unison when a car engine is turned on. Without electrical charging system, no power can be channelled to fire the spark plug, and so can not turn the engine on. Alternator is a major component in the charging system. Alternator generates AC current and converts it into DC current. Alternator helps to charge the battery and also turn on the electrical components inside the car. When the car engine is turned off, the current is supplied by the battery. When the engine is turned on, the current is supplied by the alternator. A fully charged battery should read over 12.6 volts. The actual output voltage produced by the alternator will typically be about 1-1/2 to 2 volts higher than the battery voltage. At idle, most charging systems will produce 13.8 to 14.3 volts with no lights or accessories on. A discharged battery will have a voltage of about 11.2 volts. A repeated experiment has been done to ensure the theory. The car used in the research was Proton Preve 1.6L Manual, with no added electrical accessories. An AC/DC clamp is being used to measure the value of current being produced by the alternator. And a multi-meter is being used to measure the value of voltage from the battery. The value of current and voltage were recorded before and after the engine turned on. All electrical accessories were turned on one by one. The experiment was done at engine was at idle, which is 750 RPM. The result of the experiment shows the relationship between voltage and current in the charging system. The result taken was then used to calculate the power in term of Watt. The value of power shows how much there is excessive power still can be produced.

Keywords: car charging system, alternator, battery, current, voltage.

1. INTRODUCTION

Every car has a charging system. It consists of the alternator, regulator, and the interconnecting wiring. The purpose of the charging system is to maintain the charge in the vehicle's battery and to provide the main source of electrical energy while the engine is running. Without charging system, there is no power source to recharge the battery, and the battery will become weak. Thisunfortunately,causes the engine to not have enough current to fire the spark plugs. This will force the engine to stop running.

Alternator is the main component in the charging system. It generates and produces alternating current (AC), which is then be immediately converted to direct current (DC) since most automobiles nowadays have a 12-volt DC electrical system. As long as the engine is running, all of the power for the electrical components is delivered by the alternator. This is due to the connection that ties the engine and the alternator. A timing belt connected the engine and the alternator. When the engine is running, the connecting timing belt will spin, and the alternator will run altogether with water pump, power steering pump and air conditioning compressor (Charles Ofria, 2015). The battery is actually a load to the charging system. The battery would only supply power while the engine running is when the current capacity of the alternator is exceeded. In another word, the battery will provide the needed power when the electrical system needs more power than the alternator can produce, but only for a short time. Generally, no current flows from the alternator when the engine is off. All currents come from the battery. When the engine is running, all currents come from the alternator. For battery charging to occur, the alternator's voltage must exceed the battery's voltage. Alternator may not generate sufficient charging voltage until alternator speed is greater than about 2000 RPM. The speed of an alternator is different for different type of car. The speed of an alternator depends on the speed of the engine. For a racing car, the ratio speed between engine and alternator is usually 1:1. For a drag car, the ratio is usually 1:2. And for street use, the ratio is usually 1:3.

The alternator, like most mechanical and electrical machinery, cannot withstand at maximum output for extended periods of time. Maximum output for a short period of time might be tolerable. But for most of the time, alternator operates at about three-quarter of full output potential. Also, like any other machinery, the alternator produces heat as a by-product of generating electrical power (Mark Hamilton, 2015). As the more power is produced, the more heat it makes. During the 80's, the alternator can produce power up to 1500W. Then, as technology advancing and more research development, and due to increasing power demand, the alternator has been modified and designed so that it can produce power to 2000W. This has increased the underhood ambient temperature from 110 degrees C in 1980 to 130 degrees C nowadays (Mike Bradfield, 2015). But the alternator has been designed so that it can work well at a temperature up to 200 degrees C.

The alternator is invariably in the engine compartment. When delivering current, it typically runs at 50-70 degrees C. Higher temperatures can occur. The batteries are typically located in a detached box that experiences lower temperatures than in the engine compartment. It is common for the battery temperature to be 40 degrees C below that of the alternator. Such a temperature difference reduces the alternator's ability to adequately charge the batteries and provide the load current.

Most cars, while the engine is running, have a charging system that will generally produce a voltage between 13.5 and 14.4 volts. The charging system needs to produce more voltage than the battery's rated voltage in order to overcome the internal resistance of the battery (Paul Brand, 2006). This is due to the fact that the current needed to recharge the battery would not flow at all if the charging system's output voltage was on par with the battery voltage. The charging rate will be faster if there is a greater difference of potential (voltage) between the battery's voltage and the alternator's output voltage (http://www.bcae1.com/charging.htm). Too much voltage can cause damage to the electrical components throughout the vehicle. This is where the regulator plays its part. A voltage regulator regulates the charging voltage which is produced by the alternator. It is designed to limit the voltage output of an alternator to 14.5 volts or less to protect the vehicle's electrical system. If the alternator was allowed to constantly produce all the power it could, system voltage would rise to a damaging level. At this level, the battery would overcharge, accessories and components would be damaged, and the alternator would soon overheat and burnt out. A fully charged 12-volt battery should have an open-circuit voltage of 12.6 volts. A discharged battery will have a voltage of about 11.2 volts (Popular Mechanics, 2008). But these numbers need to be checked with no load and with several hours of rest after charging.

If the alternator can produce 90 amps of current (max), and the total current demand from the electrical components, including the battery, is only 40 amps, then the alternator will only produce the necessary current (40 amps) to maintain the target voltage, which is determined by the alternator's internal voltage regulator. No matter how powerful the alternator, the output is limited according to system demands. A normal alternator might be designed to put out 100A. This might seem like a lot, but once a high-power device with hungry CPUs is added, this could easily exceed this level. Once that happens, the car will act as if the alternator has stopped working. And the battery will have to make up the difference between what the alternator is putting out and what's the car system is demanding. The battery car thus becomes completely discharged (Damien Stolarz, 2005).

Power (P) is measured in watts (W), or for high power in kilowatts (kW). 1 kW is equal to 1000 W. Power used by an electrical device is easily calculated. Just take the voltage across the device and multiply that by the current through it. *Power = voltage x current* (Stewart Robertson, 1994).

In this research, an energy audit is performed to prove some of the theories as stated above. The study will focus on the energy audit on the electricity produced by the alternator. At the moment, there is no exact information on how much percentage of current being distributed to ensure all the electrical parts are in working order. The parameter that will be taken is the amount of electricity that is produced by the alternator in total and what are the excesses amounts of the current left. The car used in this research is Proton Preve 1.6L manual. And the experiment is done at the engine is at idle.

2. METHODOLOGY

Car's battery and alternator are being tested first before continuing with the experiment to make sure they are in good condition and fully functioning.

Car's battery is being checked using digital multi-meter to get the reading of voltage. The reading is taken at initial, when the key is switch to "On", when the car engine has been started, and when electrical components in the car are being turned on.

An AC/DC Clamp is used to get the reading of alternator current output. It is being clamped at the current output cable. Same as voltage, the reading is taken at initial, when the key is switch to "On", when the car engine has been started, and when electrical components in the car are being turned on.

All the electrical components in the car are being turned on one by one by sequence.

Figure-1 is the schematic diagram of the experiment. A tachometer is used to measure the speed of the alternator. It is taken by pointing the laser to the circling belt. An AC/DC clamp is used to measure the current at the alternator's output. A multi-meter is used to measure the voltage delivered by the alternator. It is measured at the car battery.

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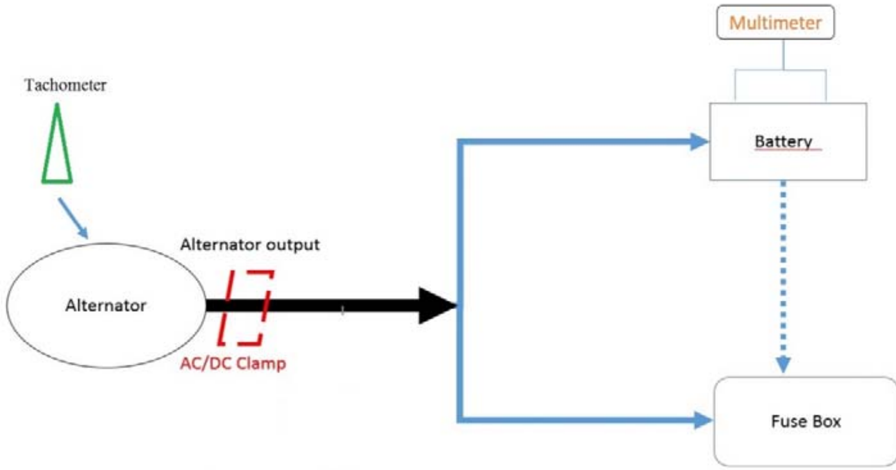

Figure-1. Schematic diagram.

Figure-2. Measuring battery reading.

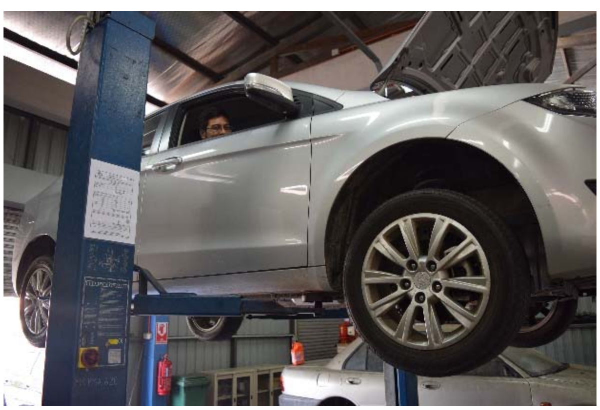

Figure-3. Car is being lifted.

Figure-4. Measuring current reading

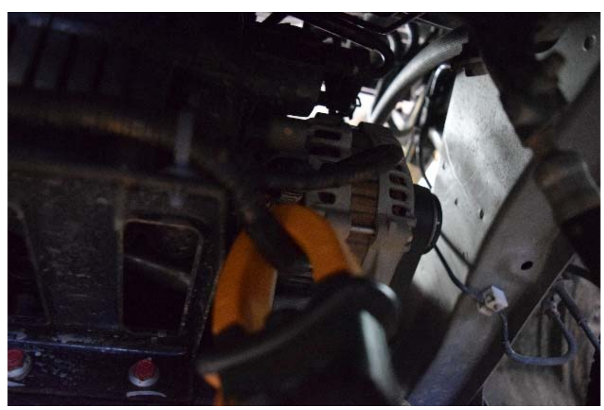

Figure-5. Alternator.

Figure-2 shows the measuring of battery's voltage reading. All the available electrical components were turned on one after another by sequence. Unplugging a wire connector at a part, and then reading voltage at the wire harness connector is not a valid test of circuit performance. After taking the voltage reading, experiment proceeds with taking the alternator's current reading. Since the alternator for Proton Preve is located at the

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bottom section of the bonnet, the car needed to be lifted, as is shown in Figure-3.

By lifting the car, it is being able to put the AC/DC clamp at the alternator current output cable. Figure-5 shows how the AC/DC clamp is being clamped at the alternator current output cable. Same as taking the battery's voltage reading, the current reading was also being taken as the electrical components were being switched on one by one, as the same sequence as before. Figure-4 above shows the reading of current as the current is flow out from the alternator.

3. RESULTS AND DISCUSSIONS

Experiment data

Table-1. Data before accessories being switched ON.

Condition	**Battery voltage output** (V)	**Alternator current output** (Amp)	**Power** (Watt)	**Alternator speed** (RPM)
Initial	12.77	0.5	6.385	0
Key at "On"	12.54	0.5	6.270	0
Engine start and idle	14.26	13	185.38	1560

Table-2. Data after accessories being switched ON.

No	**Electrical component**(s)	**Battery voltage output** (V) (Approximately)	**Alternator current output** (Amp) (Approximately)	**Power** (Watt)	**Alternator speed** (RPM)
1	Radio	13.99	13.3	186.067	1560
2	Front lamp	13.97	22.6	315.722	1560
3	Rear lamp (brake)	13.97	27.1	378.587	1560
4	Hi-beam	13.88	35.9	498.292	1560
5	Spotlight (R)(L)	13.86	48.6	673.596	1560
6	Interior lamp	13.84	50.4	697.536	1560
7	Air-cond (AC)	12.43	58.9	732.127	1560
8	Wiper, signal, hazard, power window, radiator fan	12.27	62.2	763.194	1560

Data analysis

Before starting the experiment, the car's battery and alternator are being tested first. A fully charged battery should read over 12.6 volts. The actual output voltage produced by the alternator will typically be about 1-1/2 to 2 volts higher than battery voltage. At idle, most charging systems will produce 13.8 to 14.3 volts with no lights or accessories on. Table-1 shows at initial, the battery reading is 12.77 V. And after the engine start, the battery reading is 14.26 V. This shows both the battery and alternator are in good condition.

Voltage (V) is the potential energy of electricity. Voltage can be present even if there is no current flow. For example, a car battery can have 12 volts in it even if it's not being used. That 12 volts is still there, waiting to be used, and is the battery's potential.

Table-1 shows the voltage and current reading before and after the engine start. It shows that, before the engine was started, the voltage reading is 12.77V. When the key is being put at ON, the voltage drops a bit to 12.54V. This can be said that there is a little power being drawn. The current reading stays the same, as no accessories currently being switched ON. After the engine has started, the voltage reading rise to 14.26V, and the current reading rise to 13A. When system voltage is below the setting of the voltage regulator, then the regulator causes the alternator to produce power until the voltage reaches the maximum setting of the regulator. When the engine is first being crank up, the battery voltage will be at about 12.5 or 12.6 volts. The regulator recognizes low voltage and causes the alternator to produce more power. At idle, the engine speed is 750 RPM, and the speed of the alternator is 1560 RPM. By this, the speed ratio between the engine and alternator is 1:2.

Table-2 shows the changing of battery reading when the accessories are being turned on one by one. As the more accessories are turned on, the lower the value of battery voltage. Lights, ignition, and accessories use power from the electrical system. As can be seen in Table-2, every time an accessory is switched ON, more power is drawn from the system. As power is drawn from the system, voltage drops, and immediately voltage regulator causes the alternator to generate more current. This action automatically allows the alternator to provide power for the electrical system. This is being prove by the data. As current increase, the voltage decrease. But in term of power (watt), the more electrical accessories are turned on; the higher the power is being produced.

As shown in Table-2, the air-cond (AC) takes the most voltage among all. This is because air-cond (AC) system consists of compressor, condenser and electric fans. The compressor itself uses an electro-magnetic clutch which draws more power.

Speed of alternator stays the same, and so is the speed of the engine. This is due to the work of idle speed controller (ISC). Idle speed controller regulates idle speed. Every time the A/C compressor kicks in at idle, engine speed would drop a couple hundred rpm was it not for the idle speed controls keeping things at an even keel. Idle speed will be increased when the A/C compressor is engaged, the alternator is charging above a certain voltage, to prevent the engine from lugging down.

For the case of No 8, all those accessories are being turned all together at once, as they are the type that only works in a little time. As an example, the signal only uses voltage when they start blinking. It is hard to take the reading, as it happens in an instant. This is why all the accessories which work like that are being switched ON altogether at once.

Alternator output is the amount of current that a unit is capable of producing at a specific rotational speed. For instance, a 100A alternator has a rated output of 100A, which means that it is capable of providing 100A when the alternator shaft is rotating at 6,000 RPM (Jeremy Laukkonen, 2015). In both ISO 8854 and SAE J 56, alternator testing and labelling standards indicate that the rated output of an alternator is the amount of current that it is capable of producing at 6,000 RPM.

CONCLUSIONS

This Proton Preve's alternator has a rating of 90A/12V, which means it can produce up to 90A maximum. In this experiment, after all the accessories have been turned on, the maximum current used is 62.2 A. Theoretically, there is about 28 A of current still can be produced. At idle speed, the alternator cannot produce enough power, thus the voltage will drop. It may incur additional voltage drops by adding additional loads to the system. As long as the voltage value is above 12V, it is acceptable. Power is Voltage times Current. The alternator can produce power max up to 1080 Watt. The maximum power demand is 763.194 Watt, and the minimum power demand is 186.067 Watt. There is an excessive power of 316.806 Watt still left to be used.

RECOMMENDATION

To prevent engine from lugging down, it is not recommended to put many load such as headlight, spotlight and AC when car is idling. Also, don't let the car idling for too long with all the accessories turned on, as this will put the battery not fully charged.

To ease the experiment, it is recommended to use MinuteManPlus OTC 3131. It is a multi-application electrical system tester with cart. This device can read the value of current and voltage by just clamping in onto the battery. By doing this, there is no need to use a different device to measure voltage and current value. And also, the car doesn't need to be lifted. With MinuteMan Plus, we can test discharged batteries down to as low as two volts, and it won't drain a charged battery we are testing.

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