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A Simulation of Energy Recycling Concept in Automotive Application Using Hybrid Approach

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ABSTRACT

This paper presents development of a simulation to demonstrate a relatively new hybrid approach in improving energy resources that is applicable in automotive industry. The existing hybrid approach in automotive industry is considerably efficient in terms of energy saving by switching between fuel and electricity for energy resources. However, both energy resources confront various challenges. While the electricity resources require recharging, the fuel resources are scarce and expensive. Therefore, in this paper we aim to propose a relatively new hybrid approach, referred to as energy recycling concept equipped with coordination algorithm. To simulate the proposed energy recycling concept, a prototype of Electrical Control Unit (ECU) car is built. Then, an algorithm that coordinates battery charging is developed and integrated with the ECU. Finally, the simulation of the proposed energy recycling concept equipped with the coordination algorithm is evaluated on the prototype of the ECU car. The results show that the proposed energy recycling concept that allows switching between two sources of energy is applicable to operate the ECU car prototype.

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1. INTRODUCTION

Initially, conventional vehicles were designed to use gasoline or diesel to produce energy to internal combustion engine. In the 20th century, vehicle manufacturers start to introduce various kinds of hybrid technology. Some of the popular hybrid vehicles manufacturers include Honda, Toyota, Nissan, Lexus, Mercedes, Hyundai, Ford, and Infiniti. Like the conventional vehicles, the hybrid vehicles can also be fueled. Different from the conventional vehicles, the hybrid vehicles have an electric motor and battery. The main feature of hybrid vehicles is that it allows switching of power source between fuel and electricity to operate the combustion engine. Significantly, such hybrid vehicles offer various benefits to drivers including fuel consumption efficiency, less expenditures on fuel, less risk on air pollution and health problems [1]. Indeed, there are studies on the contribution of hybrid vehicles to overcoming air contamination and global warming [2]. Besides, the dependence on non-renewable resources such as fossil fuels should not be viewed as small issue [3]. The hybrid vehicles may be classified into Series Hybrid, Parallel Hybrid, Series-Parallel and Complex Hybrid [4]. The features for each type of hybrid vehicles can be found in [1]. The advantages of such hybrid vehicles can be summarized as follows:

a) Lessen the risk of pollution [5].
b) Save cost on fuel consumption [6].

c) Fulfill potential market demand [7]

There are initiatives to improve electric vehicle performance that can be found in [8] [9]. However, the existing hybrid technology is still prone to two major limitations: dependency on electricity source for recharging and fuel source availability. Thus, in this paper, we would like to propose a relatively new hybrid approach referred to as energy recycling concept with computer-based coordinating system (CCS) to overcome these limitations.

The rest of the paper is organized as follows: Section 2 describes several components of the simulation development. Section 3 presents the results of the evaluation on the simulated prototype Finally, Section 4 concludes the simulation work and highlights a direction for future research.

2. RESEARCH METHOD

This section describes several components of the project development: the proposed energy recycling concept, the architecture of the computer-based coordinating system, the software implementation, and the hardware implementation.

2.1 Conceptual flow of energy recycling

Figure 1 shows the proposed energy recycling concept using two batteries installed in the car prototype. The computer-based coordinating algorithm is developed to ensure the batteries will take turn to be recharged. Significantly, the strength of the proposed recycling concept with the computer-based coordinating algorithm relies in its capability to maintain power supply alternately to the batteries. Consequently the continuous charging will keep the car prototype operated longer.

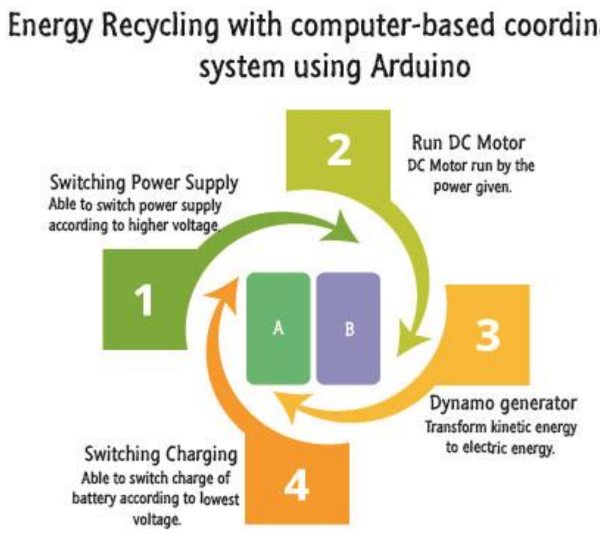

Figure 1. The proposed energy recycling concept simulated using two batteries installed in the car prototype

2.2 Architecture of energy recycling CCS

Figure 2 shows the proposed architecture of the car prototype to simulate the energy recycling concept with computer-based coordinating system (ERCS). Note that the ultimate goal of the proposed energy recycling concept is to avoid dependency on external resources such as petroleum and electricity recharging difficulties. Eventually, the reduced cost for end-users and efficient energy usage can be achieved.

2.3 Software implementation

Figure 3 shows the main interface of the coordinating software applied in the ERCS. The connection menu contains drop down list of serial port that communicate with the car prototype. The Connect button is to make connection between ERCS and the car prototype. The right panel is to view the multiple voltage values and percentage in rows.

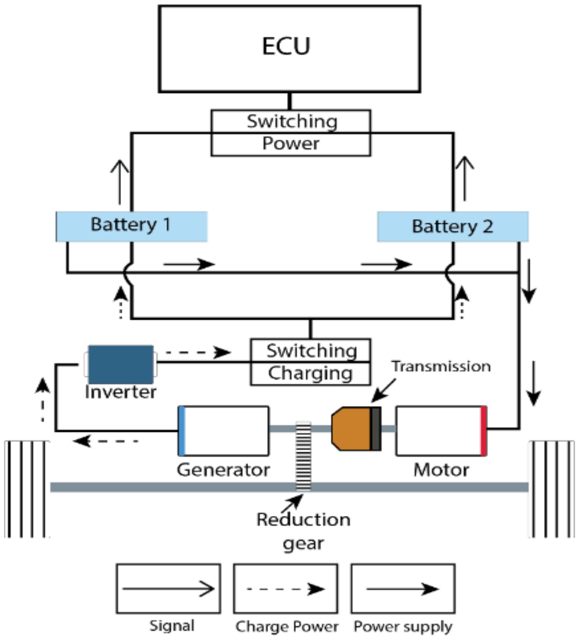

Figure 2 .Proposed architecture of ERCSA in the car prototype

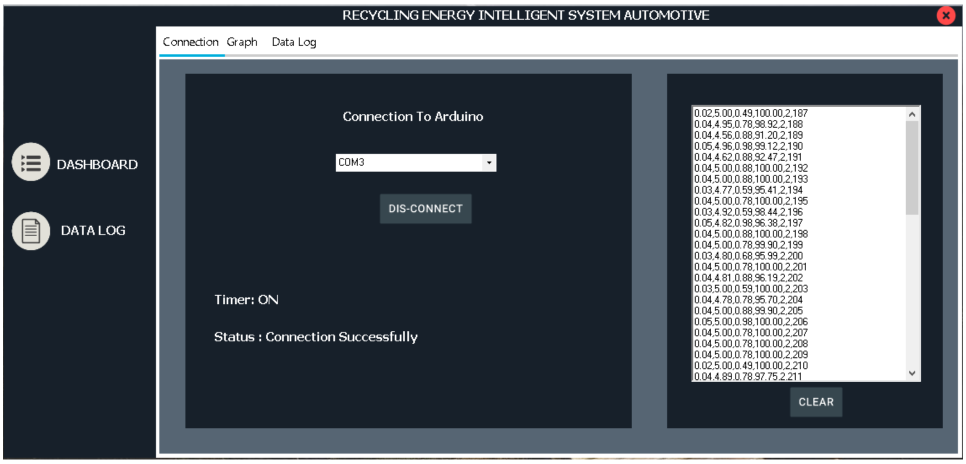

Figure 3. Main interface of ERCSA

2.4 Hardware simulation implementation

Figure 4 shows a car prototype used in the simulation of the ERCS. The car prototype was built using a remote control car.

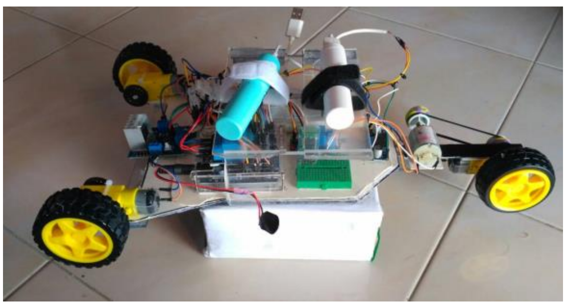

Figure 4. Car prototype of simulation

Figure 5 shows the schematic design of the integrated components. The schematic design shows the flow of the components used in the prototype. The dashed line represents the signal pins between components and Arduino and the arrow lines present flow of the voltage being used and to be charged. Note that we are not building a real car here. Instead in the simulation, we use a small scale prototype to demonstrate the proposed concept. We change the invertor of hybrid to step up voltage; the generator motor to dynamo motor and potentiometer as gas/electric pedal car. Indeed, we added some other components such as NPN transistor and two channel relays. We use two batteries as main power source to running the engine that is like replacing the fuel source to batteries. Therefore, the prototype uses only electric engine powered by any of these two batteries, one at a time. The relays react as power split devices that is to change power supply coordinate by a switching algorithm.

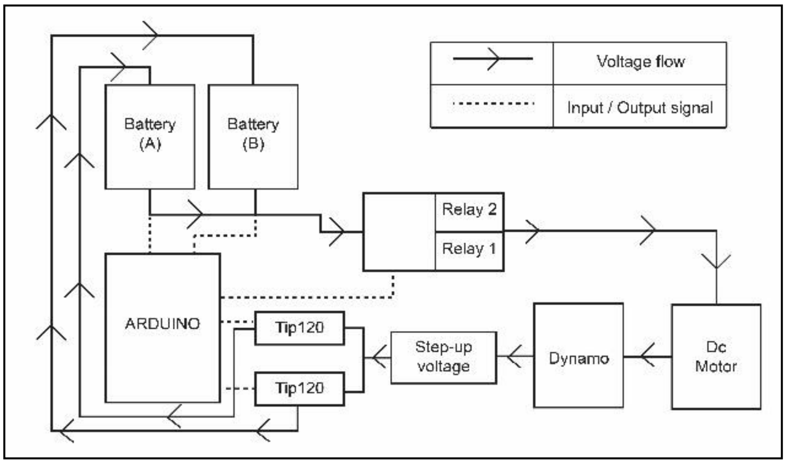

Figure 5. Schematic design of integration component

The coding for the coordinating algorithm in the ERCS prototype is built in Arduino IDE and embedded into the microcontroller. The purpose of this coordinating algorithm is to enable switching of recharging on the battery with appropriate voltage values. Below are the equations (Equations 1 to 8) used in building the algorithm to coordinate the switching procedure.The descriptions of the abbreviations used in the equations can be found in Table 1.

Table 1. Descriptions of abbreviations in Equations 1 to 8

Symbol	Description
batValA	Reading value A0
batValB	Reading value A1
voltA	Value voltage A
voltB	Value voltage B
batPerA	Percentage battery A
batPerB	Percentage battery B
voltPwmA	Voltage pwm battery A
voltPwmB	Voltage pwm battery B
chargePwmA	Charging pwm battery A
chargePwmB	Charging pwm battery B

Equation 1 shows conversion step of analogue reading to battery A voltage.

$$voltA = batValA * (\frac{5.0}{1023.0}) \quad (1)$$

Equation 2 shows conversion step of analogue reading to battery B voltage.

$$voltB = batValB * \left(\frac{5.0}{1023.0}\right) \quad (2)$$

Equation 3 shows conversion step of current voltage battery A to percentage value.

$$batPerA = \left(\frac{voltA}{5.0}\right) * 100 \tag{3}$$

Equation 4 shows conversion step of current voltage battery B to percentage value.

$$batPerB = \left(\frac{voltB}{5.0}\right) * 100 \tag{4}$$

Equations 5 and 6 show conversion of voltage battery A to pwm.

$$voltPwmA = \frac{5.0*5.0}{6.73} \tag{5}$$

$$chargePwmA = 255 * (\frac{voltPwmA}{5.0}) \tag{6}$$

Equations 7 and 8 show conversion of voltage battery B to pwm.

$$voltPwmB = \frac{5.0*5.0}{6.73} \tag{7}$$

$$chargePwmB = 255 * (\frac{voltPwmB}{5.0}) \tag{8}$$

Minimum charge voltage for each battery is 5.0 volt. Equations 5 until 8 are used to convert each battery voltage to Pulse Width Modulation (PWM) value. Moreover, the purpose of these equations are to charge the appropriate voltage and avoid overcharging. The NPN transistor will recognize the pwm value and present the value as voltage to be charged to the respective battery.

Figure 6 shows the condition used in the proposed algorithm for the computer-based coordinating (CCS) system. In this algorithm, it will trigger the command according to the voltage values. It means when the car is operating, the algorithm is able to read voltage of both batteries and convert to percentage values. Then the battery with higher voltage is assigned to act as primary power supply to provide power to the DC motor. The battery with lower voltage then requires charging. Whenever the voltage of the primary power supply is getting lower and the percentage arrives to equal or less than 15%, the algorithm is able to switch the charging. The algorithm keeps coordinating whenever the car prototype is still running. However, when the car is in idle state, then there is no switching occurs.

The voltage values are sent to the ERCS for real time monitoring. The voltage of the batteries are sent into a table. According to the voltage, we can observe the coordination of the auto switching procedure in recharging the batteries.

3. RESULTS AND ANALYSIS

The prototype car model has been used to simulate the proposed energy recycling concept with a computer-based coordinating system. The car prototype is evaluated in two conditions: (1) monitoring batteries voltage charging without the CCS algorithm and (2) monitoring batteries voltage charging with the CCS algorithm.

3.1. Monitoring batteries voltage charging with CCS

The evaluation took place about 46 minutes. The voltage is measured to observe the switching power supply, also switching recharging whenever the percentage of used battery is less than or equal to 15%. According to Table 2, initially, the algorithm indicates that percentage voltage of battery A is higher than percentage voltage battery B, thus battery A is used to be primary power supply and the battery B as the secondary power supply. Thus, battery B is charged. The switching of power supply happened in minute 21. Now, battery B became primary power supply and battery A became the secondary power supply. Thus battery A is recharged while battery B is used to supply power to the DC motor. The DC motor runs with 5.0 volt with 1.0 amperage. In minute 33, the switching power supply and switching recharging occur again. The battery A once again became prime power supply and the battery B became secondary. If the test is to be continued, then the switching of power supply and switching recharging of both batteries continue to occur. Thus the power source will never run out. The green colour indicates that the battery is used to supply power to the DC motor; the yellow colour indicates charging mode of the battery and the blue colour shows the switching power supply and switching recharging battery simultaneously.

```
INPUT: command user control
    BEGIN
        FOR (each time interval)
            counterTime ++
            IF (cp1 > cp2)
                statusOperation =1
                Relay 1= High // battery A is use
                Relay 2= Low // battery B not use
                Tip120 (1) = xv1 // not charge battery A
                Tip120 (2) = xv2 // charge battery B
                IF(cpv1 ≤ 15%)
                    statusOperation =2
                    Relay 1 = Low // battery A not use
                    Relay 2 = High // battery B is use
                    Tip120 (1) = xv1 // charge battery A
                    Tip120 (2) = Low // not charge battery
                ELSE IF (cpv2 = = 100%)
                    statusOperation =1
                    Relay 1 = Low // battery A not use
                    Relay 2 = High // battery B is use
                    Tip120 (1) = xv1 // charge battery A
                    Tip120 (2) = xv2 // not charge battery B
            IF (cp2 > cp1)
                statusOperation =2
                Relay 1 = Low // battery A not use
                Relay 2 = High // battery B is use
                Tip120 (1) = xv1 // charge battery A
                Tip120 (2) = xv2 // not charge battery B
                IF(cp2 ≤ 15%)
                    statusOperation =1
                    Relay 1= High // battery A is use
                    Relay 2= Low // battery B not use
                    Tip120 (1) = Low // not charge battery
                    Tip120 (2) = xv2 // charge battery B
                ELSE IF (cpv1 = = 100%)
                    statusOperation =2
                    Relay 1= High // battery A is use
                    Relay 2= Low // battery B not use
                    Tip120 (1) = Low // not charge battery
                    Tip120 (2) = xv2 // charge battery
        ELSE
                statusOperation =3
        NEXT
```

Figure 6. Algorithm of of the computer-based coordinating system

Figure 7 shows the voltage of both batteries with algorithm. The blue line represents voltage of battery A and the orange line represents voltage of battery B. The time interval is 1 to 46 minutes. The charging time approximately 13- 15 minutes to increase the potential ability voltage to be used again. The hybrid concept applied in the proposed energy recycling concept technique is seen to be successful.

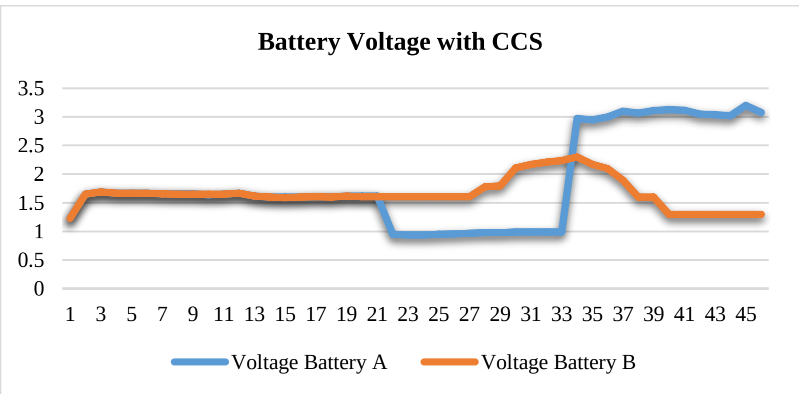

Figure 7. Battery voltage with CCS

Table 2. Voltage of batteries

Voltage Battery A	Voltage Battery B	Percent Battery A	Percent Battery B	Time Interval
1.24	1.23	24.8	24.6	1
1.66	1.65	33.2	33	2
1.69	1.69	33	33	3
1.67	1.67	33	33	4
1.67	1.67	33	33	5
1.61	1.6	32	32	18
1.62	1.62	32	32	19
1.62	1.61	32	32	20
1.62	1.61	32	32	21
0.95	1.61	19	32	22
0.94	1.61	18	32	23
0.94	1.61	18	32	24
0.95	1.61	19	32	25
0.96	1.61	19	32	26
0.97	1.61	19	32	27
0.98	1.78	19	35	28
0.98	1.8	19	36	29
0.99	2.11	19	42	30
0.99	2.17	19	43	31
0.99	2.21	19	44	32
0.99	2.24	19	45	33
2.97	2.3	59	46	34
2.95	2.17	58	43	35
3	2.1	60	42	36
3.1	1.9	62	38	37
3.07	1.6	61	32	38
3.11	1.6	62	32	39
3.13	1.3	62	26	40
3.12	1.3	62	26	41
3.05	1.3	60	26	42
3.04	1.3	60	26	43
3.02	1.3	60	26	44
3.2	1.3	64	26	45
3.08	1.3	61	26	46

3.2. Monitoring batteries voltage charging without CCS

The observation is also performed for 72 minutes to monitor batteries voltage charging without the CCS. There is no input to trigger which battery has higher or lower voltage. Indeed, the Arduino randomly choose whichever battery to act as power supply. According to table 3 and figure 8, the DC motor runs using battery B and the switching of power supply and switching of recharging on the battery do not occur. Figure 8 shows battery B became drain until the voltage runs out. The battery A is not used until the end of the observation. At the end of this evaluation phase, the DC motor of in the car prototype is finally stopped because the power has run out. The red cells in Table 3 indicates idle state of battery A and the yellow cells indicate battery B is used as power supply.

Table 3. Monitoring performance voltage batteries no algorithm

Voltage Battery A	Voltage Battery B	Percent Battery A	Percent Battery B	Time Interval
0.76	0.22	15	4	1
0.73	0.27	14	5	10
0.66	0.24	13	4	20
0.7	0.18	14	3	30
0.72	0.13	14	2	40
0.74	0.11	14	2	50
0.74	0.1	14	1	60
0.72	0.08	14	1	70
0.75	0.08	15	1	71
0.75	0.08	14	1	72
0.75	0.08	14	1	72
0.74	0.08	14	1	72

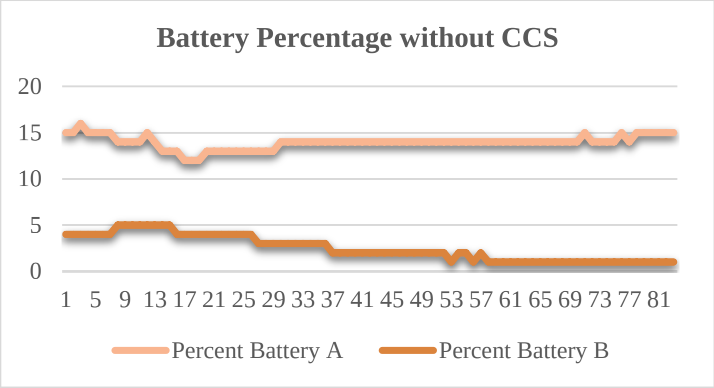

Figure 8. Batteries voltage of without CCS algorithm

The evaluation result shows that switching of recharging between the two batteries do not occur if the CCS algorithm is not applied.

4. CONCLUSION

In this paper, a relatively new hybrid approach, known as energy recycling concept has been proposed. To demonstrate the proposed energy recycling concept, two major tasks were performed: a car prototype was built (hardware) and a computer-based coordinating algorithm (software) was developed. Both components, the hardware and software were integrated. The evaluation results show that the proposed energy recycling concept is successfully performed. The implemented CCS algorithm is able to perform switching of primary power supply and switching of rechargeable battery. Note that in this paper, the proposed idea of energy recycling concept has been evaluated in a simple simulation of a car prototype. However, the principal idea in the proposed energy recycling concept is seen to be applicable in automotive industry that can reduce dependency of fuel availability and electricity resources.

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