Design of EV Go: Kart Electrical System

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Abstract
This report is aimed at design of electrical system for an electric go-kart. The equipment should be cost-efficient, have proportional specific energy and specific power to run the kart at racing track, should be less prone to thermal hazards etc. The important aspect of the electrical system is safety and capacity. Were safety plays a vital role to minimize the damage and the capacity of the electrical accumulators helps in fulfilling full-fledged requirements for the kart in the view of racing.
Many key factors are considered for the best equipment and required calculation are made to achieve the requirements. From the resultant calculations the capacity of the accumulator and the capacitors relays are purchased in order to run the go kart with perfect capacity and required power.

Keywords: Accumulator, capacity, electrical system

1. Introduction

An electric battery is a source of electrical energy consisting of one or more electrochemical cells with external connections to operate electrical equipment. When a battery supplies current, its positive terminal is the cathode and the negative terminal is the anode. The pole labeled negative is the source of electrons that flow through the external electrical circuit to the positive pole. When the battery is connected to an external electrical load, the redox reaction transforms high-energy precursors into lower energy products, and the difference in free energy is transferred to the external circuit as electrical energy.

Primary cells are designed to be used until they run out of energy, after which they are discarded. Their chemical reactions are usually not reversible, so they cannot be recharged. When the battery's supply of starting materials runs out, the battery stops producing current and is useless. Primary cells or batteries can generate current immediately after assembly. They are most often used in low-power, portable devices that are used only intermittently or far from an alternate power source, such as in alarm and communication circuits where other power is only available intermittently.

Secondary cells, also known as secondary cells or rechargeable batteries, must be charged before first use; they are usually in a discharged state with active materials. Secondary batteries can be charged; in other words, their chemical reactions can be reversed by applying an electric current to the cell. It regenerates the original chemical raw materials so that they can be reused, recharged and recycled many times. Rechargeable batteries are (re)charged with an electric current that reverses the chemical reactions that occur during discharge/use.

Introduction to Lithium-ion or Li-ion Battery:

A lithium-ion or lithium-ion battery can be a rechargeable battery that uses a reversible reduction of metal ions to store energy. it is the dominant battery type used in portable consumer electronics and electric vehicles. In addition, it sees significant use for grid-scale energy storage and military and regional applications. Compared to various reversible battery technologies, Li-ion batteries have high energy density, low self-discharge, and no memory effect (although the small memory effect that LFP cells claim is due to poorly designed cells).

Figure 1: Lithium-ion cell

Lithium-ion batteries can be a safety hazard if not properly designed and manufactured, as the cells contain flammable electrolytes and can cause explosions and fires if damaged or improperly charged. Many advances have been made in the production of safe lithium-ion batteries. Lithium Ion All solid state batteries are designed to remove the burning electrolyte.

Both environmental concerns have prompted some researchers to improve the efficiency of minerals and alternatives such as iron-air batteries. Research areas for lithium-ion batteries include extending life, increasing energy density, improving safety, reducing cost, and increasing charging speed.

2. High Voltage Circuit of EV Go-Kart

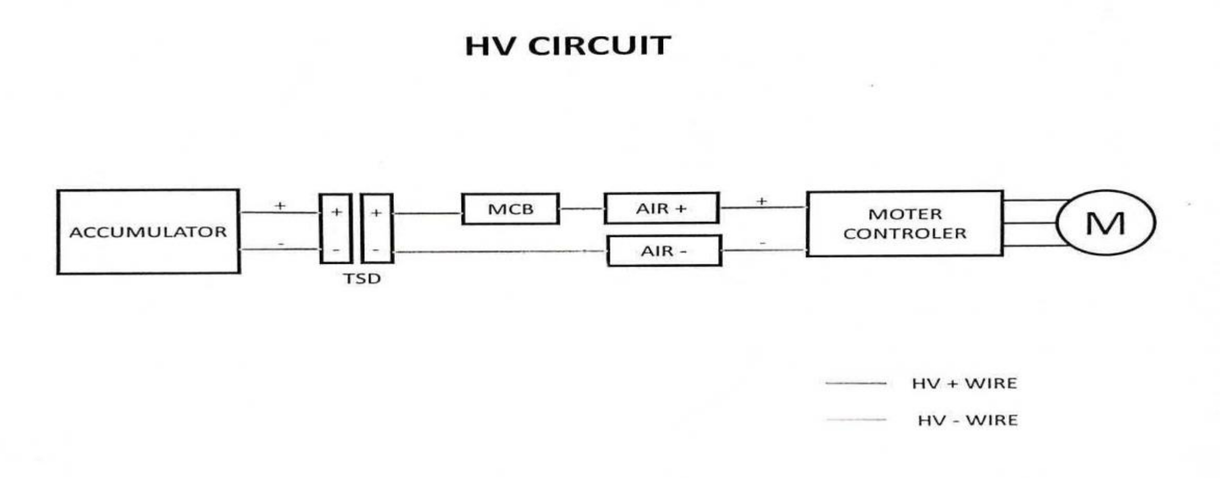

Figure 2: High Voltage Circuit

2.1 High Voltage Components of EV Go-Kart

a. Accumulator

A battery is an energy storage device that receives, stores and releases energy as needed. A lithium-ion or lithium-ion battery can be a rechargeable battery that uses a reversible reduction of metal ions to store energy. it is the dominant battery type used in portable consumer electronics and electric vehicles. In addition, it sees significant use in grid-scale energy storage and military and regional applications.

Based on our requirements, we chose a 64V And 75 amps lithium-ion phosphate battery, which consists of 5 cells connected in parallel and 20 cells connected in series, where each cell has 3.2volt.

Each cell voltage: 3.2volt
Number of cells :20×5=100 cells Peak voltage:64V
Continuous rating:1.5C Peak Rating=5C Charge=75Ah
Accumulator Discharge Power (Peak)= (Peak Rating ×Charge) ×Voltage

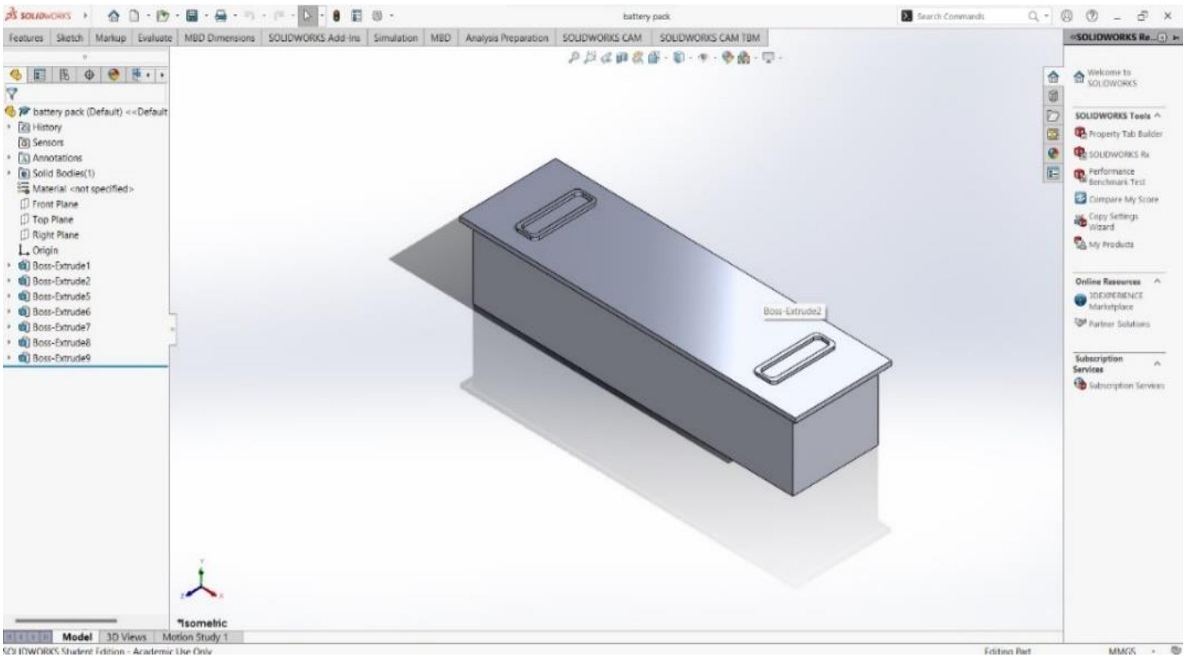

Figure 3: Cad Model of Accumulator Casing

Accumulator calculation:

Lithium-ion battery:
Voltage:64 volts Ampere:75 amps
Each cell voltage: 3.2volt Number of cells :20×5=100 cellsPeak voltage:64V
Continuous rating:1.5C Peak Rating=5C Charge=75Ah
Accumulator Discharge Power (Peak)= (Peak Rating ×Charge) ×Voltage
= (5×75) ×64
= 24000watts

= 24kw

Accumulator Discharge Power (continuous)= (Continuous rating charge) ×Voltage

= 1.5×75×64

= 7200watts

= 7.2kw

Accumulator Peak Voltage = Individual cell voltage × no. of parallel cells

= 3.2×20

= 64V

Cell type: Cylindrical cell

Because of the light weight, we are using a cylindrical cell.

b. Accumulator management system or Battery management system

A battery management system (BMS) is a technology designed to monitor a battery pack, which is an array of battery cells electrically arranged in a row x column matrix configuration to enable the delivery of a target voltage and current over a specified period of time. expected load scenarios.

The oversight that a BMS provides usually includes:

- Monitoring the battery
- Providing battery protection
- Estimating the battery's operational state
- Continually optimizing battery performance
- Reporting operational status to external devices

c. Accumulator Charger

A battery management system (BMS) is a technology designed to monitor a battery pack, which is an array of battery cells electrically arranged in a row x column matrix configuration to enable the delivery of a target voltage and current over a specified period of time expected load scenarios.

Figure 4: Accumulator Charger

d. Motor Selection

NAME	DC Motor	Brushless DC motor	Three Phase AC Induction Motors	Switched Reluctance Motors (SRM)
Power Density	2.5	4	5	4
Efficiency	2.5	4	4.5	3.5
Controllability	3	4	5	3.5
Reliability	3	5	4.5	4
Cost	5	5	3.5	4
Complexibility	5	4	3	3.5
Safety	4	5	5	4
TOTAL	**26**	**31**	**30.5**	**28**

Table 1: Motor Selection

DC motor runs on anything that lies between 12 and 192 volts. In addition, more torque is generated from DC motors that lead to a cost-cutting aspect. DC motors are classified into three categories which are Brushed DC Motor, BLDC or Brushless DC Motor and Stepper Motor. Brushed DC motors are widely used in electric vehicles to retract, position and extend power side windows. These motors are suitable for many applications due to their low cost. However, commutators and brushes tend to wear relatively quickly due to their constant exposure, resulting in regular maintenance and frequent replacement.

e. PMSM (Permanent Magnetic Synchronous Motor**)**

A PMSM motor works on the same principle as a synchronous motor. PMSM motors start as short circuit motors. A rotating magnetic field is created in the air gap when the three-phase winding of the stator receives voltage from the three-phase power supply. At synchronous speed, the rotor field magnetically locks onto the stator poles, creating torque and allowing the rotor to continue rotating.

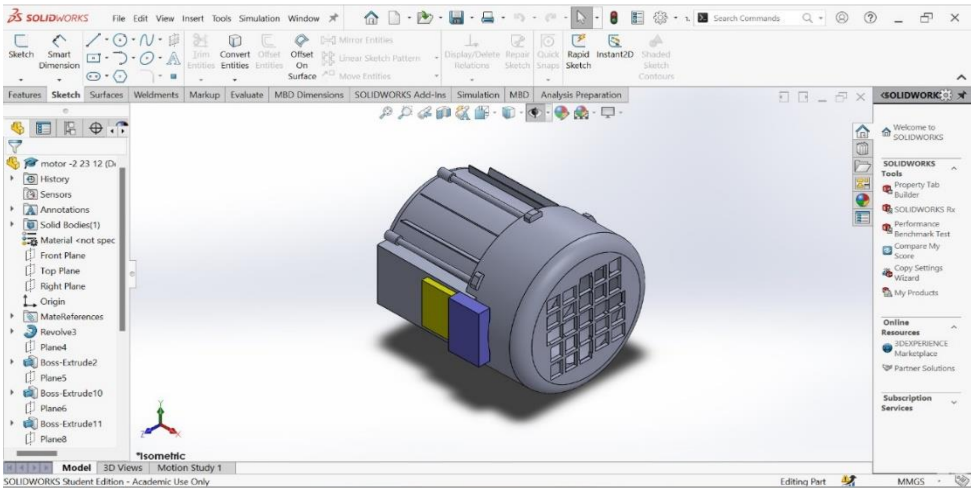

Figure 5: Cad Model of the Motor

It relies on a rotating field that generates an electromotive force at synchronous speed. When 3-phase power is applied to the stator winding, a rotating magnetic field is created between the air gaps. This produces a torque when the rotor field poles keep the rotating field at synchronous speed and the rotor rotates continuously. Since these motors are not stand-alone motors, it is necessary to provide a variable power supply. Permanent magnets are used as a rotor to generate a constant magnetic flux, they operate and lock synchronously. These types of motors are similar to brushless DC motors.

EMF and Torque Equation

In a synchronous machine, the average EMF induced per phase is called dynamic induces EMF in a synchronous motor, the flux cut by each conductor per revolution is Pϕ Weber
Then the time taken to complete one revolution is 60/N sec
The average EMF induced per conductor can be calculated by using

$$(P\phi N / 60) \times Zph = (P\phi N / 60) \times 2Tph$$

Where **Tph = Zph / 2**
Therefore, the average EMF per phase is,

$$= 4 \times \phi \times Tph \times PN/120 = 4\phi fTph$$

Where Tph = no. Of turns connected in series per phase
ϕ = flux/pole in weber
P= no. Of poles
F= frequency in Hz
Zph= no. Of conductors connected in series per phase. = Zph/3
The EMF equation depends on the coils and the conductors on the stator. For this motor, distribution factor Kd and pitch factor Kp is also considered.
Hence,

$$E = 4 \times \phi \times f \times Tph \times Kd \times Kp$$

The torque equation of a permanent magnet synchronous motor is given as,

$$T = (3 \times Eph \times Iph \times \sin\beta) / \omega m$$

f. PMSM Motor Controller

A motor controller is a device used to control an electric motor that is coordinated in some predetermined manner. The controller can have a manual or automatic system to start and stop the motor, reverse the direction of rotation, select and adjust the speed and limit the torque. It is also used to protect the motor against overloads and malfunctions.

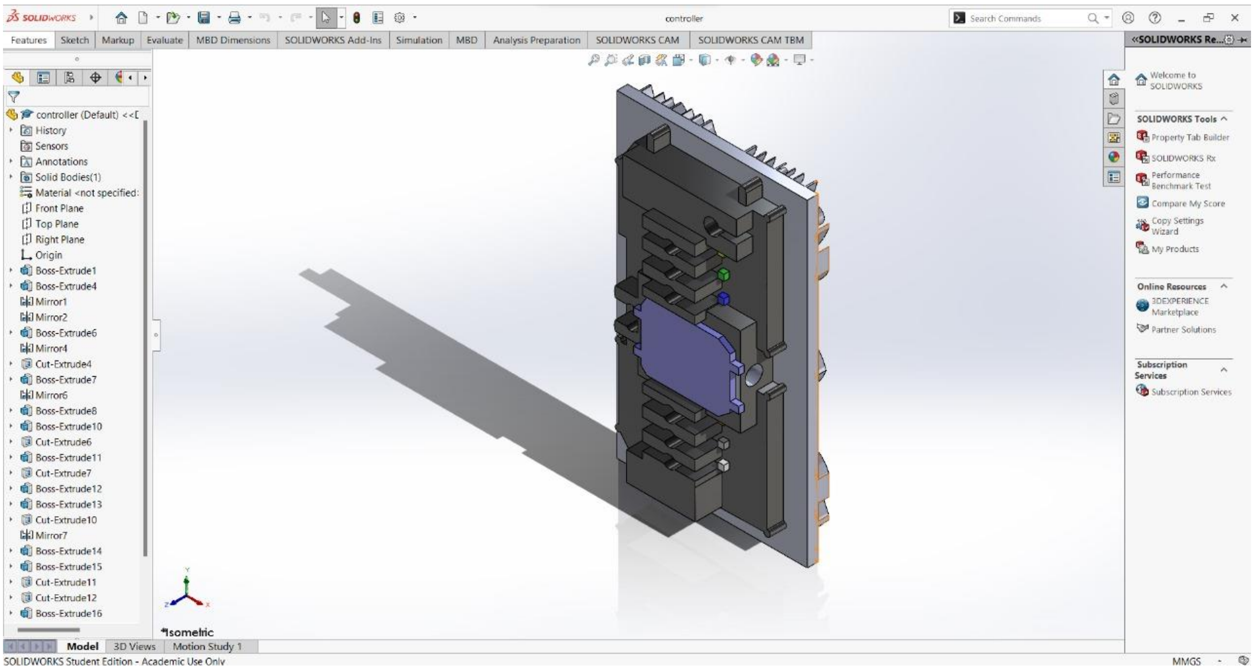

Figure 6: Cad Model of Controller

Motor Controller Calculation:

Motor controller discharge power(peak)=Rated Voltage × Peak protection current

= 60×120

= 7.2kw

Motor controller discharge power(continuous)=Rated voltage ×Rated current

= 60×80

= 4800watts

= 4.8kw

Rated Voltage	60V
Peak protection current	120A
Rated power	7200W
Under Voltage Protection	53V
Throttle voltage	1V to 4.5V
Phase commutation	120 degrees
Brake De-energize	High
Heat dissipation	Natural cooling
Ambient temperature	20 degrees to 60 degrees

Table 2: Motor Controller Specifications

g. Tractive System Disconnect

The Tractive System is the part of the Vehicle that carries the current to power your motors. This includes all the High Voltage equipment's like Accumulator, Inverters, motors and the motor controller. The other components that belongs to TS as per their work and ratings are AIRs (Accumulator isolation relays) , Pre Charge Relay, Discharge Relay, HVDs (High Voltage Disconnects), Fuses etc.

In order to boost battery life and efficiency, the battery management and module design approach needs to be improvised by using partial discharge cycles and avoiding high charge and discharge currents, because high currents play excessive stress on batteries and thus reducing cycle life. Limiting battery temperatures extends battery life as well.

Figure 7: Tractive System Disconnect

Current Rating	450A
Voltage Ratings	600A
Contact Barrel Wire Size (AWG/mm2)	1/0 to 300 mcm 53.5 to 152.0
Maximum Wire Insulation Diameter (mm)	27.9mm
AVG Contact Resistance (micro-ohms)	50
Insulation Withstanding Test Voltage (Volts AC)	2200
Contact Retention Force (ibf)	150
a. No load (Contact/Disconnect Cycles) b. Under Load Hot Plug 250 cycles @120V	To 10,000 100A
Avg. Connection/Disconnect (ibf)	30
Operating Temperature Range	(-20º to 105º/-4º to 221º) (-40º to 125º/-40 to 257º)

Table 3: Tractive System Disconnect Specifications

h. Single Pole MCB (Miniature Circuit Breaker)

An MCB is an automatic circuit breaker that opens when too much current flows through the circuit. It can be closed again without a manual switch. In the case of a fuse, it must be replaced or reconnected after its use, depending on the type of MCB. This is why fuses are known as single sacrificial devices. This is the main reason why MCBs are used as a fuse alternative in most equipment. In addition, whenever there is a fault in the circuits, the MCB switches automatically trip and the fault in the device can be easily detected.

Circuit Diagram of Single Pole MCB

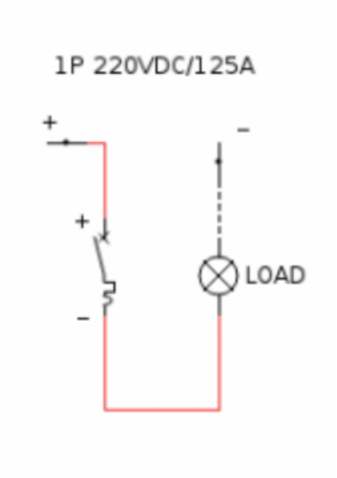

Figure 8: Circuit Diagram of Single Pole MCB

i. Accumulator Isolation Relay

An accumulator isolation relay is a component used in electrical systems, particularly in automotive applications. It's designed to isolate the battery or accumulator from the rest of the electrical system when the vehicle is not in use, preventing unnecessary battery drain. This helps ensure that the battery remains charged and ready to start the vehicle when needed. Is there anything specific you'd like to know about accumulator isolation relays An accumulator isolation relay is a component used in automotive systems, particularly in hybrid and electric vehicles.

Circuit Diagram of Accumulator Isolation Relay

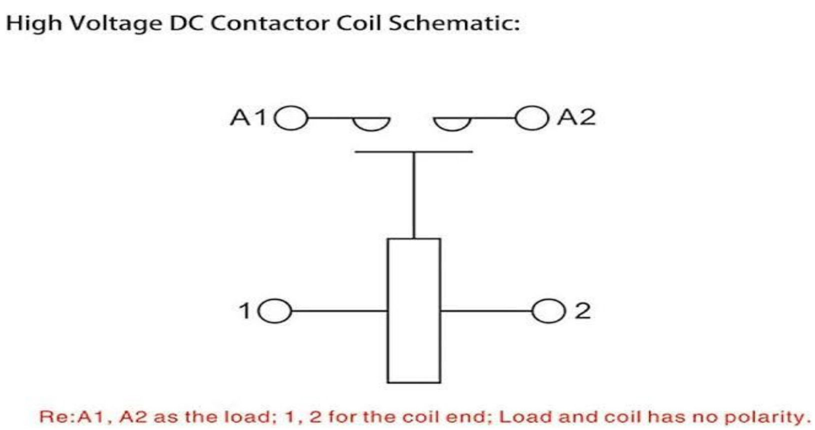

Figure 9: Circuit Diagram of Accumulator Isolation Relay

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3. Low Voltage Circuit

Electric Vehicles (EVs) are powered by a high-voltage Electric vehicle battery but they usually have an automotive battery as well, so that they can use standard automotive accessories which are designed to run on 12 V. They are often referred to as auxiliary batteries. The auxiliary battery can power additional accessories such as headlights, taillights, turn signals, or other electronics without draining the main battery, ensuring that the primary power source remains dedicated to driving the go-kart.

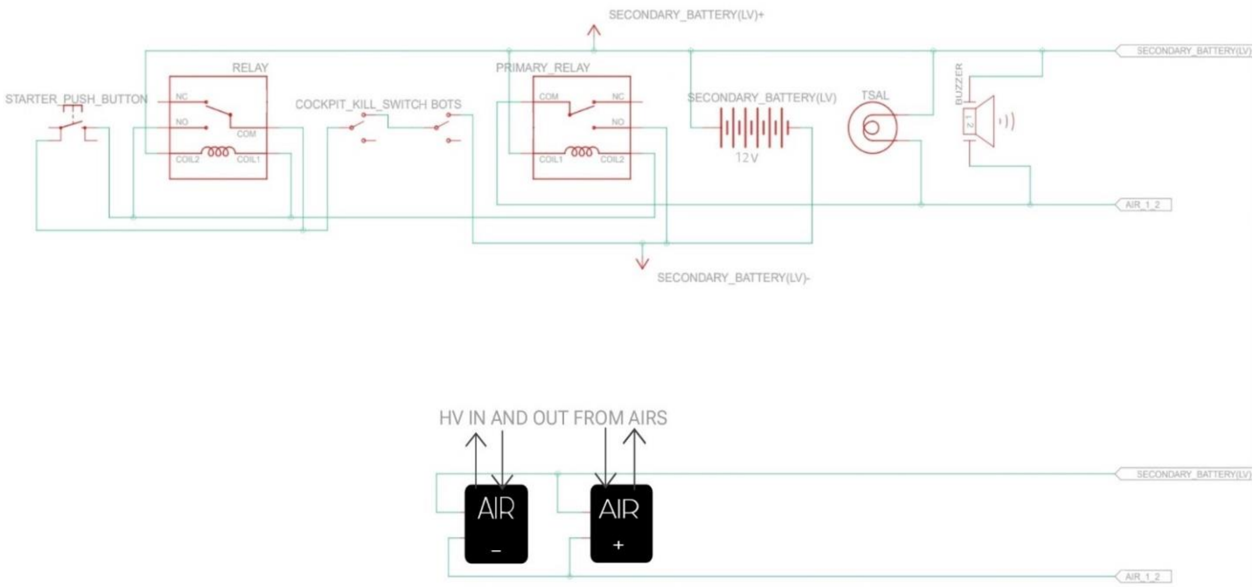

Figure 10: Low Voltage Circuit of EV Go-kart

Secondary Battery or auxiliary battery

Integrating a 12-volt auxiliary battery into the go-kart's electrical system requires careful consideration of voltage compatibility, wiring configuration, and charging mechanisms. It's essential to ensure that the auxiliary battery works seamlessly with the existing electrical components and charging system to avoid compatibility issues or damage to the main battery.

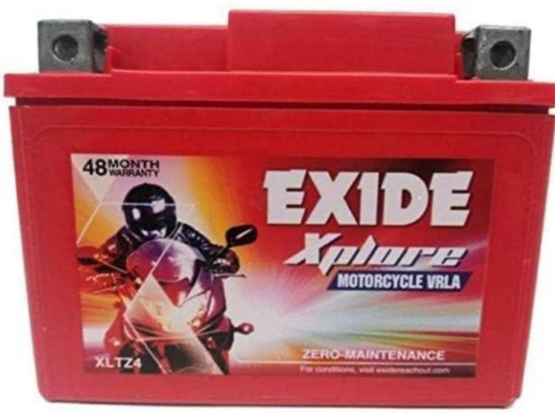

Figure 11: Auxiliary Battery

Kill Switches

Kill switches on electric go-karts serve as safety mechanisms to quickly and effectively shut down the vehicle in case of emergencies or to prevent unauthorized use

Figure 12: Kill Switch

Tractive System Active Light

The tractive system active light, also known as the propulsion system active indicator, is a visual indicator used in electric vehicles, including go-karts, to signal when the propulsion system is actively engaged and providing power to the vehicle.

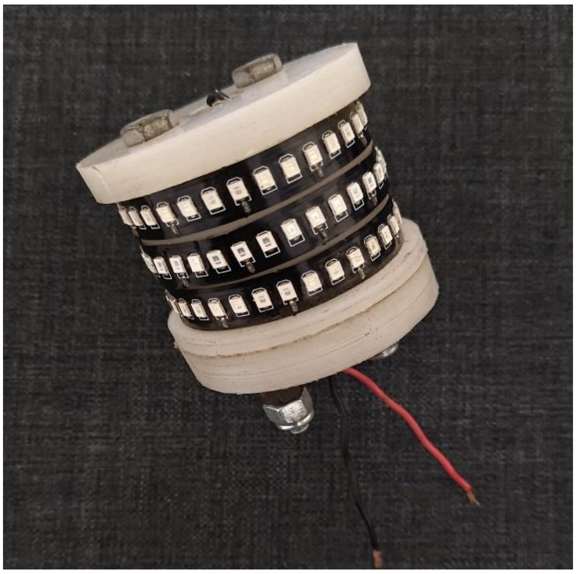

Figure 13: Tractive System Active Light

Brake over Travel Switch

The brake override travel switch, also known as the brake over-travel switch, is a safety feature commonly found in electric vehicles, including go-karts. This switch is typically located within the braking system and is activated when the brake pedal or lever reaches its maximum travel distance, signaling the controller to cut power to the motor and bring the vehicle to a stop.

Figure 14: Brake Over Travel Switch

Brake Light

In go-karts, brake lights serve a similar essential safety function as in other vehicles. They are typically mounted at the rear of the go-kart, often integrated into the rear bodywork or as standalone units. When the driver applies the brakes, either through a foot pedal or hand lever, the brake light illuminates, alerting other drivers or track personnel of the go-kart's deceleration. This signaling is crucial for preventing rear-end collisions, especially during high-speed races or when multiple go-karts are on the track simultaneously. Ensuring the visibility and proper functioning of brake lights on go-karts is paramount for promoting safe driving practices and minimizing the risk of accidents on the track.

Figure 15: Brake Light

Electronic Accelerator Pedal

An electronic accelerator pedal, also known as drive-by-wire or throttle-by-wire, replaces the traditional mechanical connection between the accelerator pedal and the throttle body with electronic sensors and actuators. It allows for more precise control over engine power and enables features like cruise control and traction control. Additionally, it can improve fuel efficiency and enable integration with other vehicle systems for enhanced performance and safety.

Figure 16: Electronic Accelerator Pedal

Pin Relay

A 5-pin relay is an electromechanical switch utilized in electrical circuits to regulate the flow of current. Comprising a coil, stationary contacts, and movable contacts, this relay operates by activating its coil with a low-power signal, which then magnetically attracts or repels the movable contacts, either closing or opening the circuit. Pin 85 and 86 are designated for the coil, while pins 30 and 87 are for the normally open (NO) contacts, controlling current flow in the load circuit. Additionally, pin 87a serves as the normally closed (NC) contact.

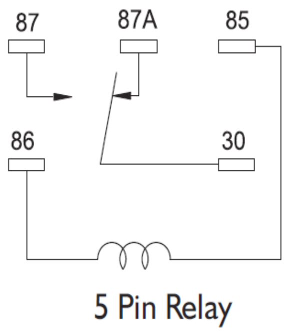

Figure 17: Circuit Diagram of 5-Pin Relay

AMS Cock pit Lights

AMS cockpit lights in electric go-karts are sophisticated lighting systems strategically positioned within the cockpit area to serve various functions. These lights enhance driver visibility by illuminating the dashboard, controls, and instrumentation, ensuring optimal performance even in low-light conditions. Additionally, they provide critical feedback to the driver, such as battery levels or system warnings, through color-coded signals or patterns, enhancing safety and awareness during races or practice sessions.

Figure 18:AMS Cockpit Light

4. sResult

Based on the study the Electrical system and their equipment that has been used in the kart are much familiar to get a optimum power output from the accumulator and continuous power supply and maintenance of the voltage and current difference among HV and LV circuit chain. The calculation part of the power house and the requirement of the desired output are suitable to use these appliances. To discusses about the overall result of the electrical system focuses on the performance evaluation as compared to the previous system, efficiency and energy management throughout the kart to run in the track of total laps.

Figure 19: EV Go-kart with full wiring

Figure 20: EV Go-kart at final Endurance test

5. Conclusion

In conclusion, the electric go-kart electrical systems play a crucial role in the performance, efficiency, and safety of the vehicle. From the battery management system to the motor controller and wiring harness, each component must be carefully designed and integrated to ensure optimal performance and reliability. As electric go-karts continue to gain popularity for both recreational and competitive purposes, advancements in electrical system technology will further enhance the driving experience, pushing the boundaries of speed, range, and responsiveness. Understanding and optimizing electric go-kart electrical systems are crucial for achieving competitive advantage in racing. By leveraging advanced technologies and fine-tuning system parameters, teams can unlock the full potential of electric go-karts on the track, pushing the boundaries of performance and innovation in motorsport.

Safety is paramount in racing, and electric go-karts are equipped with various safety features to protect drivers and equipment. Circuit breakers and emergency shut-off switches are essential for quickly disconnecting power in the event of a malfunction or accident, preventing potential harm to drivers and spectators.

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