Hybrid OTTPA Super Mini Modified Tractor Design
Phase 1 - Research and System Concept

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Project Overview

The goal of this project is to design a mini modified hybrid tractor that complies with the Ontario Truck & Tractor Pulling Association (OTTPA) regulations while maximizing competitive performance. The project progresses through three main phases:

- **Phase 1:** Conceptualization, planning, and research (current phase). This includes defining systems, layout, and requirements.
- **Phase 2:** Calculations and CAD design, translating concepts into working models.
- **Phase 3:** Reflection and documentation, finalizing the report and evaluating results.

The tractor will use a **series-hybrid drivetrain**, where a diesel generator powers a battery pack, which then supplies current to electric motors. This setup provides instant torque and smooth control compared to traditional mechanical drivetrains. Each rear motor is designed to produce around **1500 Nm** of torque, sufficient to lift the tractor's front end—a key advantage in tractor pulling events.

This report summarizes the work completed in **Phase 1**, including research on design rules, drivetrain and frame layout, control systems, safety planning, and system integration.

1 OTTPA Rules & Constraints

To ensure fairness and safety, the OTTPA enforces strict regulations that shape every aspect of the design. These limits define the tractor's size, weight, and required safety features.

Summary of Key Constraints

Type of Constraint	Requirements	Compliance Notes
Weight & Size Limits	Max weight: 2050 lbs Max length (front of rear axle): 8 ft Max tread width: 6 ft	Lightweight materials chosen Fits within frame limit Ensures stability
Tires	18.4 x 16.1 allowed; no radials	Meets standard pull tire rule
Hitch & Drawbar	6–13" from rear axle; max height 13"	Fits pulling geometry
Drivetrain	Reverse lockout required Driveshaft shielding (5/16" steel or 3/8" aluminum)	Included in motor control system Added in mechanical layout
Electrical	Kill switch, battery disconnect, air shut-off	Included in design
Safety	Roll cage, seatbelt, neck brace, fire suppression	Fully compliant
Fenders & Skid Plates	Must protect tires and drivetrain	Included in CAD plan

Table 1: Summary of OTTPA Rules and Design Constraints

2 Hybrid System Architecture

The tractor uses a **series-hybrid configuration**, removing any mechanical link between the engine and the wheels. The diesel generator charges the batteries, which power two electric motors mounted on the rear axle. This allows for precise control and instant torque response.

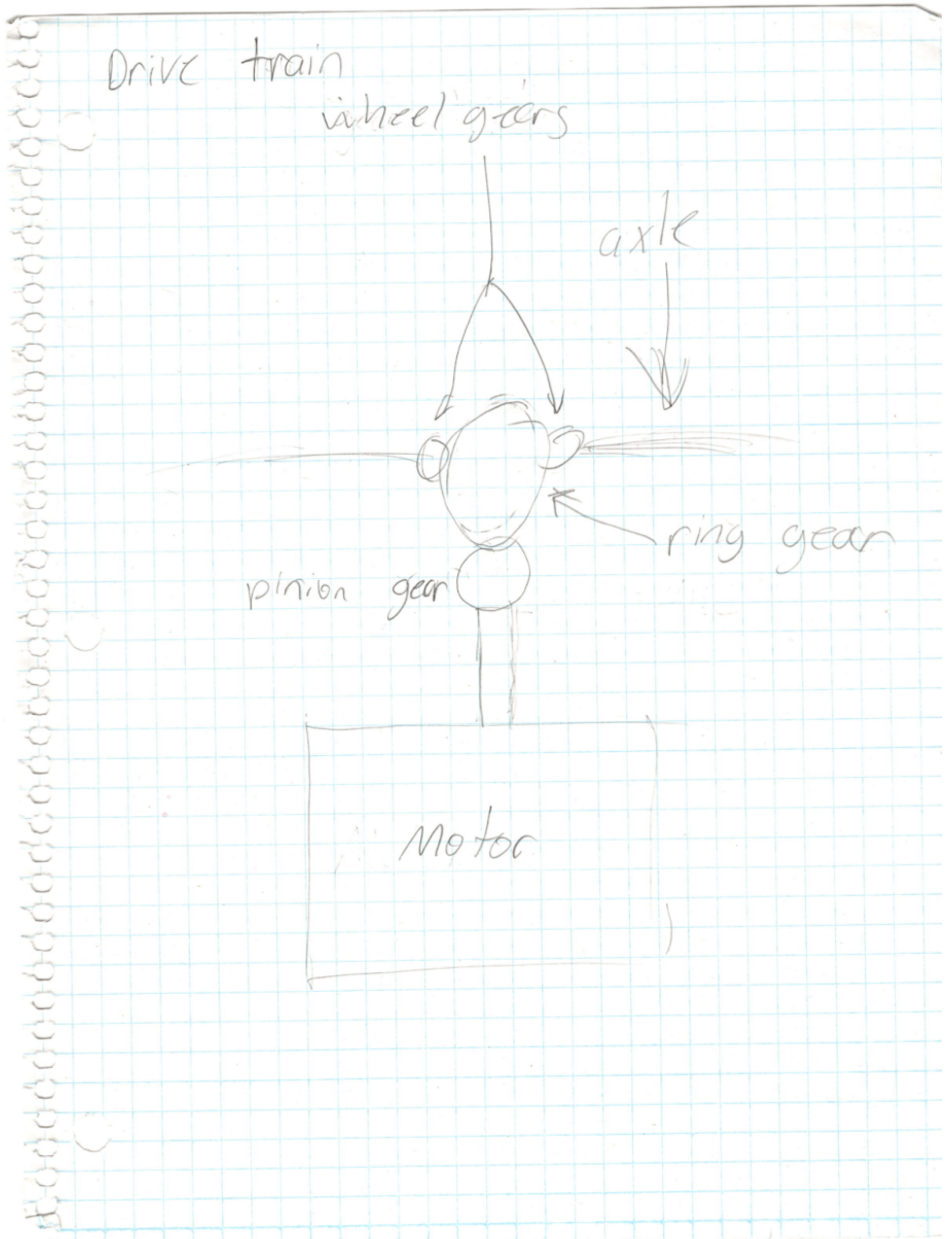

Figure 1: Power flow in the series-hybrid drivetrain.

Energy Flow Path

1. **Generation:** Diesel engine drives a 20 kW alternator at constant speed.
2. **Storage:** 48V 100Ah battery pack stores and supplies energy.
3. **Control:** Dual motor controllers manage torque with field-oriented control.
4. **Propulsion:** Rear electric motors provide 1500 Nm each through gear reduction.

3 Torque and Power Analysis

Torque determines the pulling force available at the wheels. The basic equation is:

$$T = F \times r$$

where T is torque, F is traction force, and r is wheel radius.

Assuming a traction force of 6000 N and wheel radius of 0.25 m:

$$T = 6000 \times 0.25 = 1500 \text{ Nm per wheel.}$$

This ensures sufficient pulling force to lift the front end. The diesel generator (about 20–25 kW) provides steady power while the battery handles transient peaks.

4 Control System Concept

The control system manages energy between the generator, batteries, and motors for stable performance. Key functions include:

- Supervising battery charge and generator output.
- Regulating torque through motor controllers.
- Monitoring sensors for voltage, current, and temperature.
- Providing safety cutoffs through kill switches and disconnects.

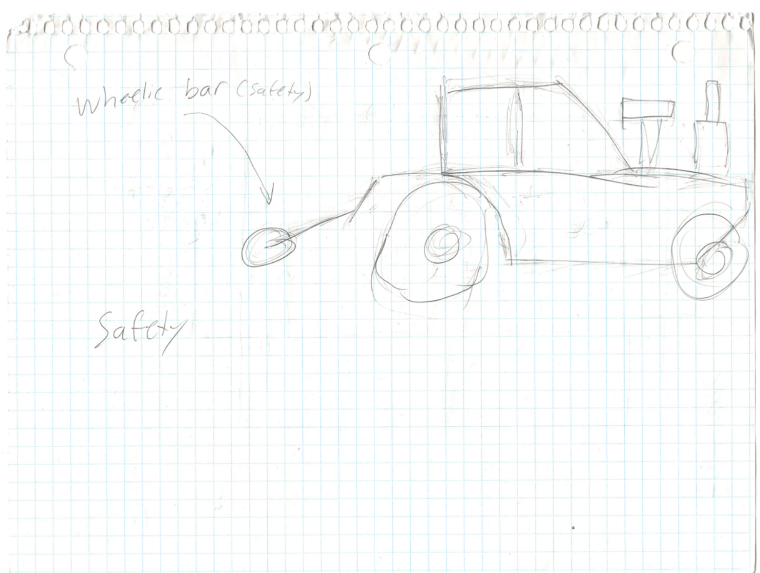

Figure 2: Safety and electrical control layout.

5 System Components

Component	Function	Example Specification
Diesel Generator	Provides power to charge batteries	20 kW output
Battery Pack	Energy storage and buffer	48V, 100Ah
Motor Controllers	Regulate motor torque and speed	Dual-channel FOC
Rear Motors	Provide propulsion	1500 Nm torque each
Sensors	Monitor system parameters	Voltage, current, RPM, temp

Table 2: Core Hybrid System Components

6 Frame Design

The chassis uses a triangulated steel space-frame for maximum rigidity with minimal weight. Electric motors are mounted directly on the rear axle, eliminating driveshaft losses. All electrical components are enclosed for safety and serviceability.

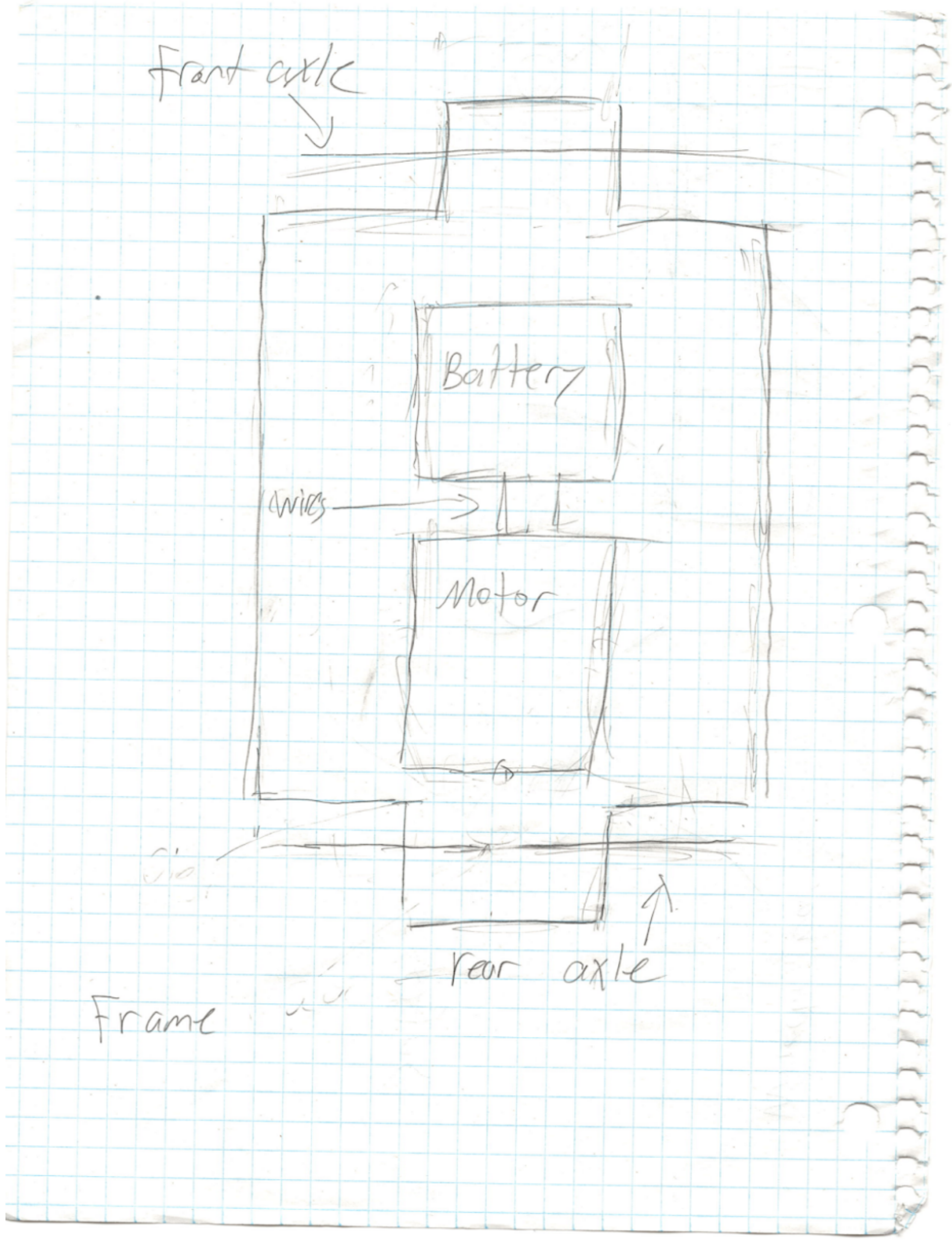

Figure 3: Chassis layout showing frame and component placement.

7 Additional Features

The hybrid design allows for future enhancements:

- Regenerative braking for energy recovery.
- Torque vectoring for improved traction.
- Real-time telemetry and data logging.
- Adaptive control algorithms for efficiency.

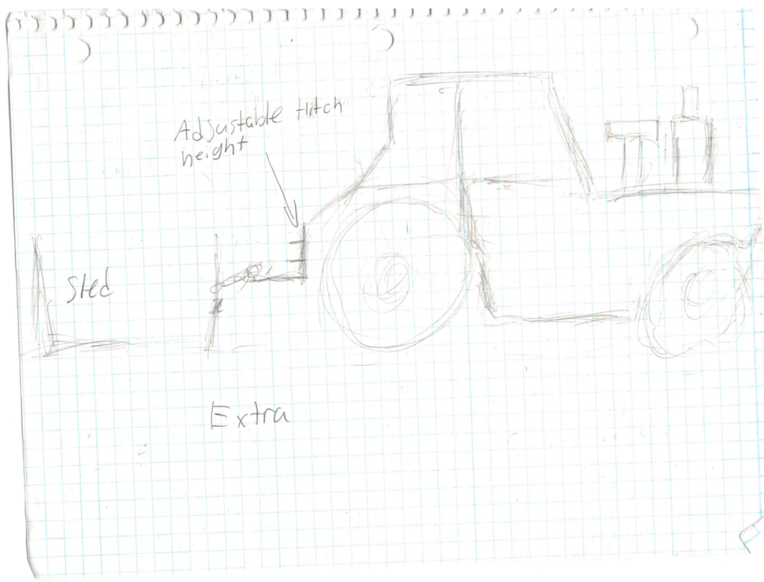

Figure 4: Future-ready hybrid system enhancements.

8 Reflection

This project helped me understand how hybrid systems integrate electrical, mechanical, and control engineering principles. I learned to calculate torque and power, design within safety constraints, and document technical work professionally. This experience directly supports my goal of pursuing mechatronics or mechanical engineering and developing efficient hybrid power systems.