Motor & Inverter Selection Review

Name: Yuki Suter

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Your Project Information

What part/system are you designing?

- The system being selected is the motor and inverter combination. The task is to choose the most appropriate motor and inverter combination for the vehicle we are making.

What are the end deliverables for this project?

- By the end of the project, a motor and inverter should be selected, with crucial information such as datasheets and 3D models collected and have readily available for other UGR X-24 members to use.

Who are the 'stakeholders' of your work?

- Vehicle Dynamics

  VD require the motor selection before they can run any useful simulations on the behaviour of the vehicle. Without the motor selected they have no information on the acceleration, top speed or general powertrain characteristics of the vehicle.

- Unsprung Mass & Drivetrain

  USM require the motor to be selected before they can develop crucial components of the drivetrain. Without knowing the final motor choice they cannot create an appropriate drivetrain with the gearing required for the final motor.

- Chassis & Structures

  Chassis require the motor to be selected before they can make decisions on the suspension system. The main part of the motor they would need to know about is the dimensions of the selected motor, as these could influence the shape or size of the suspension system.

- Other High-Voltage Powertrain Engineers

  Most other high-voltage powertrain engineers require the information on the motors before making decisions. The Battery Architecture engineer requires information on operating voltage and current before a cell type can be chosen. Motor and inverter cooling can only be decided once the motor is chosen, and without information on the batteries from the battery architecture engineer, the accumulator cooling, and TSAC and cell holder engineers cannot make decisions on their on designs.

Your Preliminary Concept

What requirements have you established for your design/system?

- Must give us a successful lap time at a competition.
- Should not be overly heavy, since outboard motors are used which would effect vehicle dynamics.
- They cannot be too big, so that the 10-inch wheels can be used for this vehicle.
- They should stay within the parameters of the FSUK 2024 rules (voltage rating etc).
- Motor and inverter selected should be cross compatible.
- Inverter should be able to communicate with other systems, by CAN-bus.
- The motor should be capable of regenerative braking.

Briefly summarise any market research you have conducted into this concept – what systems already exist that solve your end goals?

- 6 companies were researched, most with only 1 suitable motor for our vehicle.
- Plettenberg and MGM have multiple offerings, all of which where relevant were compared.
- A spreadsheet was created highlighting our potential options, allowing us to see which is better suited to our needs.

UGR-X24 Motor Selection

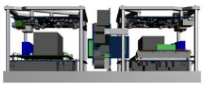
Rim Diameter (mm): 254

Motor Make & Model	EMRAX	AMK	Neu Motors	Plettenberg				MGM		Zytek
	188	FSE Kit (A2370DD)	4440	Nova 15 LW	Nova 15	Nova 30	Nova 50	REB30	RET60	ZPM-3
Mass (kg)	7.1	3.55	5.207	1.44	2.5	5	11.5	8.15	7.5	9.2
Diameter (m)	0.188	0.096	0.127	0.138	0.129	0.198	0.274	0.267	0.169	0.17
Length (m)	0.077	0.135	0.152	0.132	0.077	0.093	0.104	0.101	0.123	0.163
Peak Power (kW)	60	12.3	24	15	15	30	50	40	35	60
Peak Torque (Nm)	100	21		40	40	80	142	150	100	50
Continuous Power (kW)	37		12					30	25	40
Continuous Torque (Nm)	56	9.8								
Max Voltage (v)	490		400	120	320	320	320	800	800	400
Max RPM	8000	20000		8000	11000		5600	4000	8000	16500
Price (GBP)		15650	1500							
Power-Weight Ratio (kW/kg)	8.45	3.46	4.61	10.42	6.00	6.00	4.35	4.91	4.67	6.52
Torque-Weight Ratio (Nm/kg)	14.08	5.92		27.78	16.00	16.00	12.35	18.40	13.33	5.43

What concept is currently looking like the best option for your Design/System?

The best choice is looking to be the AMK FSE kit. This kit comprises of the DD5-14-10 motor and the KW-S5-FSE inverter.

RACING KIT 2WD

Piece	Illustration	Description
1		2 independently operating inverters including the special firmware FSE, mounted on a liquid cooled plate.
2		Performance and weight optimized 10 pole synchronous servo motor with motor encoder system.
1		Commissioning and parameterization software AIPEX PRO (inclusive Company/Institute license)
1		USB cable with ferrite core
1		RACING KIT training for 2 people
1		10 hours support by phone or email

Version	Price
RACING KIT 2WD	20.300,00 €
RACING KIT 2WD inclusive AMKmotion Sponsoring	15.650,00 €

Why have you chosen this concept?

- Deciding on a motor:

  Motors were researched based on our design criteria. The most important part of this was power. By the rules the total power output by the vehicle had to be below 80kW as we were going for 2 outboard motors. This meant looking primarily for motors around the 40kW mark. However we would later find out that most motors of this power are quite large and fall outside of the acceptable limits for our particular vehicle's dynamics. As such the search was narrowed to be for as powerful a motor possible without exceeding the strict demands of the vehicle dynamics and unsprung mass sub-teams. Namely motor diameter and mass. The motors up for consideration after researching specs were the Nova 15LW, 30, or AMK DD5 (FSE kit).

  Simulations were then run on Optimum lap for the potential motors. This gave us enough information to make an informed decision, as it allowed us to see accurate information on the predicted acceleration, lap times and top speeds. It also allowed us to check what the best gear ratio would be for each motor. Seeing as we would be achieving the peak power output of the motors on the 75 metre stretches, 75m straight track was used to simulate and compare. This was since the motors are unlikely to reach peak power at any other points in the track, making this the make or break part of the motor selection. Screenshots of the simulation results can be found at the bottom of this document, showing how the AMK motor seems to achieve the fastest lap time but also the fastest 75m straight time suggesting a better acceleration.

- Deciding on an inverter/controller:

  The inverter/controller could not be chosen until the motor was decided. Fortunately, the AMK motor comes with an inverter meaning there is guaranteed compatibility. Other inverters for the other potential motor choices were explored before coming to a decision on the motor. Research was therefore carried out on potential inverters for the NOVA series of motors (15LW or 30). Whilst a good option for the NOVAs were found, the AMK proved to be more performant than the NOVA motors, meaning the FSE kit was chosen, including the inverter with it.

What do you feel are the next steps for improving your concept?

- The concept would be better if proper information on regenerative braking characteristics could be found. With this information details such as required battery size could be more accurate, potentially giving us better lap times. It may be possible to extract this information from manufacturer data, which should be tried next to improve this.

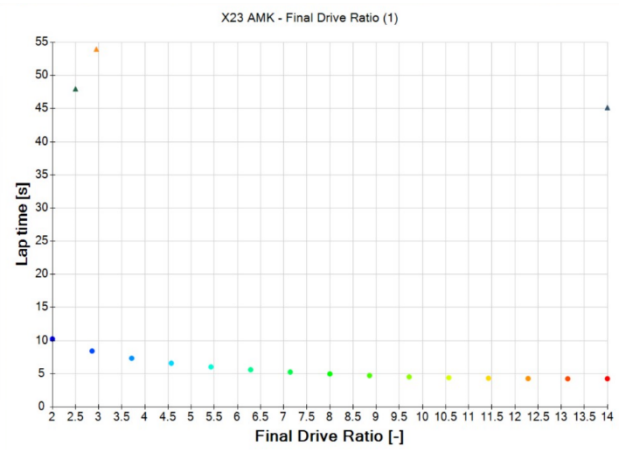
Motor & Inverter Information:

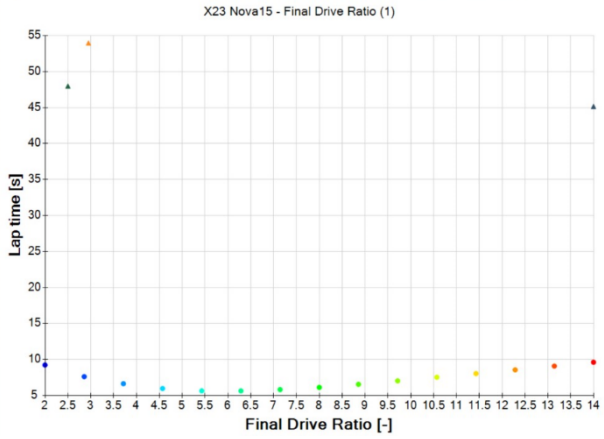
Documents, 3D models and manufacturer website:

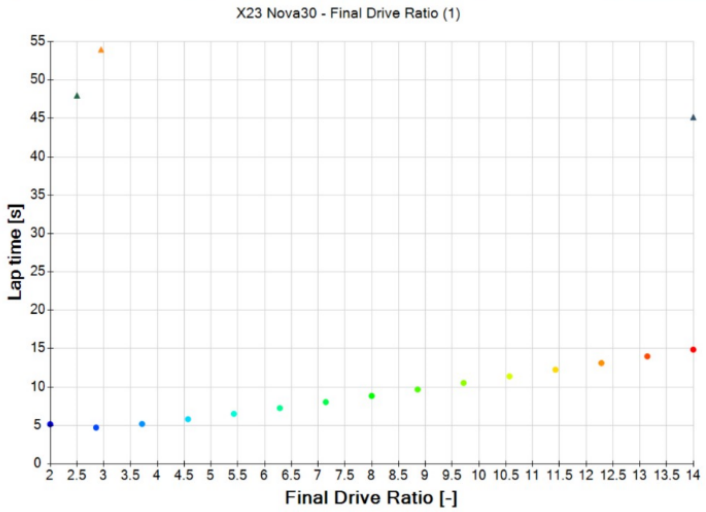
https://doku.amk-motion.com/en/Doku_en.htm#projekt/doku-cd_html5/topics/amk_automotive.htm?TocPath=Formula%2520Student%2520Electric%257C_____0

Simulation Graphs:

On the 75m straight sections:







On the FSAE Austria Endurance 2012 track: