Team 968/254 Preliminary Winch Calculations – 2010 FRC Breakaway
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Power equals work over time:

$$\frac{F \cdot d}{550 \cdot t} = HP$$

1 HP = 550 lbf-ft/s

For now, neglect acceleration, assume 155 lb robot, needs to raise steadily for a distance of 6 feet, in a time of 1.5 seconds.

$\frac{155lb \cdot 6ft}{550 \cdot 1.5s} = 1.127HP = 840Watts$ needed. We *should* have this available with 4 CIMS.

Let's check: Peak power = 335 Watts for each CIM, = 1340 Watts peak for the system. 840/1340 = 62% of peak power. **We need to keep an eye on current draw through the 40A breakers.**

Now, let's check how this will work in actuality with the drive train.

Assume a 3" diameter spool/drum, with a cable tension of 155lb (assuming a constant velocity pull.)

$T = F \cdot r = 155lb \cdot 1.5in \cdot \frac{1ft}{12in}$ =19.375 lbf-ft torque needed on the spool

Gearing from the CIM to the spool: 12:45 primary, then 30:48 secondary.

Let's work backward, from the spool to the CIM, to determine the torque on the CIM when lifting.

$19.375lbf \cdot ft\left(\frac{30driver}{48driven}\right)\left(\frac{12driver}{45driven}\right)\left(\frac{1}{4CIM\,Motors}\right)$ =0.807lbf-ft on each CIM

Stall torque of each CIM = 2.2 Newton-meter, = 1.622lbf-ft

% of stall = $\frac{.807}{1.622}$ = 50%

Stall current for CIM motor is 133A, therefore, if a 3" spool is run off of high gear (30:48) each CIM will pull 66.5 Amps!!! **Another reduction is needed!**

We should shoot for the current to each CIM to be no more than 30A when lifting, to be safe.
This gives a decent margin for overloads (stuck against something).

$\frac{Previously\_Calculated\_66.5Amps}{Target\_30Ampls}$ **= 2.22:1 additional reduction needed, to draw 30A while (smoothly) lifting.**

Now let's see how fast it will go with this gearing.

No-load speed of CIM is 5300 RPM.

We are at the operating point of 30 Amps (loaded smooth pull). To figure out the speed of the motor at this point, we refer to the motor curve. Torque and speed are an inverse relationship to each other, and a direct linear relationship to current and voltage respectively.

$\frac{30A}{133A}$ =22.5% of stall = 77.5% of no-load speed = ~4100 RPM (loaded).

Going through the reductions:

$$5300RPM\left(\frac{12}{45}\right)\left(\frac{30}{48}\right)\left(\frac{1}{2.22}\right) = 397RPM$$

Does this meet or exceed our goal of raising 6 feet in 1.5 seconds?

$397RPM(3in\_spool)(\pi)\left(\frac{1ft}{12ij}\right)\left(\frac{1\min}{60\sec}\right)$ = **5.19 ft/sec loaded line pull speed**

$\frac{6\,feet}{5.19\sec}$ **= 1.15 sec to lift 6 feet**

Remember though, we have not taken into consideration the additional force and current required to accelerate the robot from zero speed to lifting speed, in the upward direction. Considering this fact, ***we can consider the above design to be just sufficient*** to meet the target parameters.

How should the above design be modified for optimization? Reiterate!

Slightly increase (numerically greater) the gear reduction between the drive train, and the spool, or reduce the spool diameter. Then, reiterate the calculations. This will reduce the current draw, leaving margin to overcome a "stuck" condition before tripping circuit breakers.

Note, if we wished to make the gearbox larger (which we do not), we could drive the winch directly from a 64 tooth gear, from the 14 tooth gear on the intermediate shaft, and this would provide the additional reduction of at least 2.2:1 needed for a 3" spool (2.85:1 to be exact).