Assignment 2 in the course “Hybrid Vehicle Drives” 2018

A Full Electric Tractor

Background

The heaviest workload of an agricultural tractor is plowing. Depending on a number of parameters, like soil composition and moisture and the width and depth of the plow, the pulling force of the tractor and the tractor speed combines to rather high tractor power levels, like 100…300 kW. This is not a problem to supply with a diesel driven tractor. However, if the same tractor is made fully electric, it still cannot carry more than 100…200 kWh of batteries that essentially will be discharged after less than an hour at 200 kW operation. A normal plowing campaign on a normal size farm takes days.

As an example, recharging a 200 kWh (energy optimized) battery that is discharged to e.g. 40 kWh level can at best be done at C=2, i.e. 400 kW, and that would take more than half an hour since full charging power cannot be maintained during the whole charging period. Thus the operation time and charging time would be about the same which is NOT acceptable - the operational time will be way to low. In addition, no normal farm has a power connection to the electric power grid at electric power levels above 100 kW. Thus any solution for running a tractor at a power level significantly higher than the maximum grid power means that some kind of grid support is needed probably connected to a photovoltaic energy source.

The hypothesis behind this home assignment is the following:

1. The tractor is a conventional, a hybrid or a full electric. The maximum traction machine power is 300 kW.
2. The tractor has a battery that is either I) fixed in the tractor and cannot be replaced nor externally charged (hybrid) or II) replaceable and rechargeable (full electric).
3. The battery system is made in such a way that batteries in modules of 50 kWh can be swapped between the tractor and an (autonomous) service vehicle.
4. The batteries modules are, when not installed in the tractor, instead installed in a grid energy storage system located at the farm. The batteries are transported between the tractor and the grid energy storage system by means of the service vehicle.
5. The grid energy storage is connected to a photovoltaic system. The PV system, if big enough, can balance the lack of power capacity of the grid to supply the tractor with power.

The assignment

1. You shall run the different tractors types according to hypothesis 1 above and evaluate:

   a. The benefit of hybridisation compared to conventional drive in this application. What is the optimal balance between combustion engine and electric traction machine power.

   b. The requirements to facilitate full electric operation given assumptions listed below. There are two charging options; I) The tractor itself drives back to the grid energy storage and charges from a local fast charging station at C=1.5 or II) The batteries are transported from the grid energy storage to the field and swapped with the tractor. Some relevant questions are: - How big batteries do the tractor need to carry? - How much solar cell capacity is needed to balance the power supply? - How big grid energy storage is needed? What will be the uptime in the two different charging scenarios?

2. You can assume that:

   a. The tractor can take batteries in modules of 50 kWh, that weigh 500 kg per module and can be discharged down to 80 % DoD. The tractor weight is 6 tons without any batteries.

   b. The farmer has 200 acres (1 acre = 10 000 m^2) of field to plow. The plow is 3 meters wide and the speed is 10 km/h when plowing. The plowing is autonomous and is done 20 hours per day, as few days in a sequence as possible.

   c. The service vehicle can carry up to 10 battery modules.

   d. The service vehicle needs 5 minutes to swap battery between itself and the tractor or the grid energy storage and 15 minutes for transport between the energy storage and the field. Thus a full roundtrip takes 2x15+2x5=40 minutes.

   e. The farmer's grid connection can supply up to 100 kW and during the plowing campaign 50 kW is needed for other purposes on the farm.

   f. You can pick any position in Sweden of your choice for defining the solar power and energy capacity. The plowing should be made in September, which defines the solar capacity that can be utilized at that time of the year. Use e.g. https://www.solkollen.nu/test/ to calculate the power and energy capacity of a solar cell installation of a certain size, location, orientation etc.

3. To your help you have a version of the "Parallel" hybrid simulation file, extended with a plowing drive cycle and a tractor vehicle model. These can be downloaded from course hompage.

4. Write a report presenting the thoughts behind your solution and the results, supported with a presentation of your simulation model, your control strategy and simulation results. Submit the report by e-mail to Philip and Meng no later than **Oktober 22nd**. Use the filename student1_student2_assigment2…". The report must be complete including front page and table of contents, all in one file. The report must be in "pdf" or Microsoft Word format.