STAR Method:

Situation: Set the scene and give the necessary details of your example

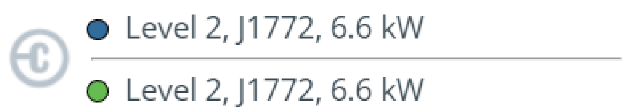
Task: Describe your scope and responsibility in that situation

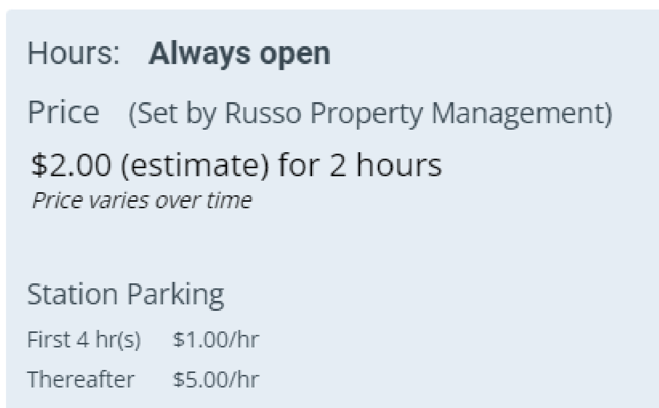
Action: Explain in detail what steps you took to address the situation

Result: Share what outcomes your actions achieved

Situation:

Some property owners institute inconvenient pricing policies around EV charging that add unnecessary complications:





A Tesla Model 3 has an 82 kWh battery pack which can drive the car 358 miles. An average American drives 13,500 miles per year, meaning they need to charge ~ 3 times per month. When low, say ~ 10% state of charge, you would need to replenish 74 kWh at 6.6 kW charge speed, which will take roughly 11 hours overnight.

Hours 0 through 4 will be priced reasonably at 0.1515 / kWh, making an effective “full tank” cost $12.43 for 358 miles. Not bad.

If you leave the car overnight to fully charge, the remaining 7 hours will cost $35 more. This makes the effective “full tank” cost $44.05 for 358 miles. This is less compelling. With gas being $3.26 a gallon, a car only needs to get 27 MPG to be more cost effective.

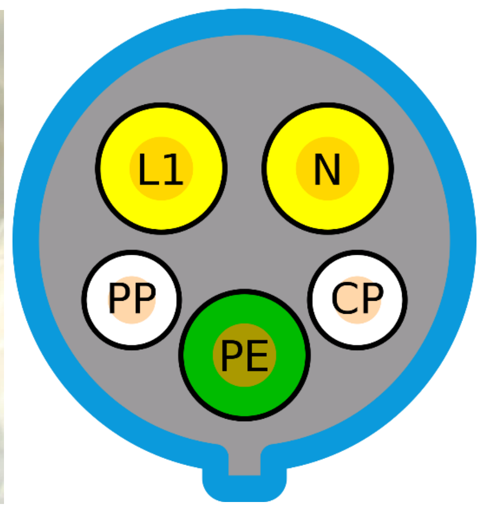
If you started charging at 11 PM before going to bed, you can circumvent this problem by setting alarms every 4 hours throughout the evening and restarting your charging sessions at 3 AM and 7 AM. This is awful. We can do this better.

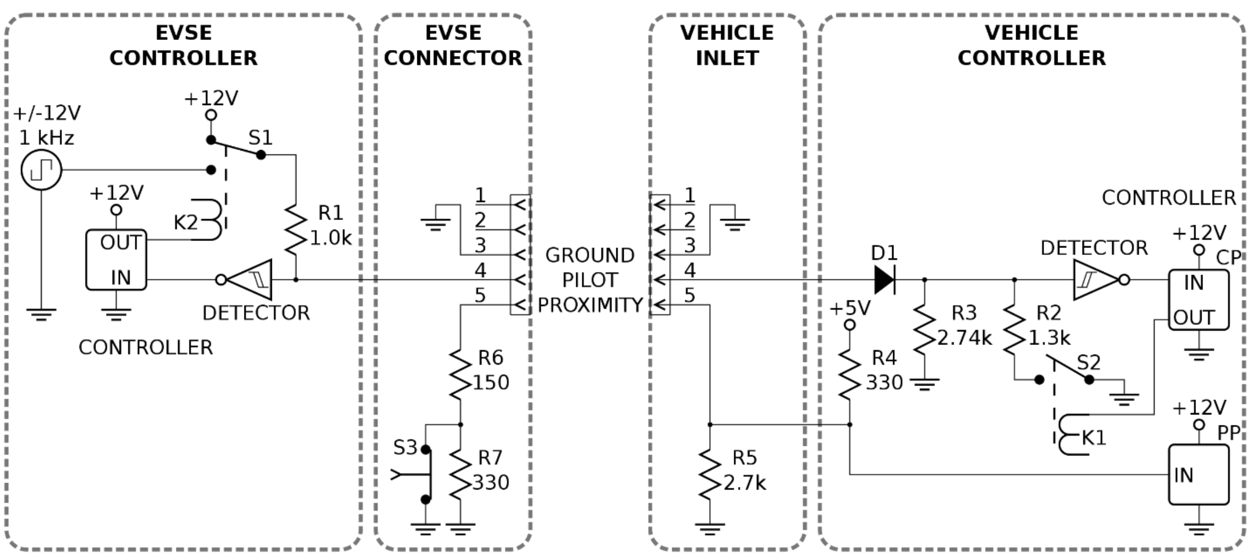
Task:

Circumvent the property owner's inconvenient pricing structure with an ethical and well thought out engineering solution.

Action:

I started by digging into the J1772 charging standard, which is North America's standard for electrical connectors for electric vehicles maintained by SAE International. Most AC charge points at offices, hotels, and shopping centers utilize this standard for offering EV charging.





The pins:

L1: "AC Line 1"

N: "AC Neutral" for 120 V Level 1 charging or "AC Line 2" for 208–240 V Level 2 charging

PE: "Protective Earth" aka Ground

PP: "Proximity Pilot" aka "plug present", which provides a signal to the vehicle's control system so it can prevent movement while connected to the electric vehicle supply equipment, and signals the latch release button to the vehicle.

CP: "Control Pilot" is a communication line used to signal charging level between the car and the EVSE, and can be manipulated by vehicle to initiate charging as well as other information. The signal is a 1 kHz square wave at ±12 volts generated by the EVSE to detect the presence of the vehicle, communicate the maximum allowable charging current, and control charging begin/end

There is also a Release Mechanism switch which we will be exploiting as well:

The **proximity detection pin** is connected to a switch in the connector release button. Pressing the release button causes the vehicle to stop drawing current. As the connector is removed, the shorter control pilot pin disconnects first, causing the EVSE to drop power to the plug. This also ensures that the power pins will not be disconnected under load, causing arcs and shortening their life. The ground pin is longer than the other pins, so it breaks last.

When you perform this manually, a user walks up to the car, presses the button which is a mechanical latch to disconnect it from the car. This also engages an electrical switch which causes the proximity signal to go through an additional resistor (R7), changing the voltage of that signal. Then the J1772 handle is removed from the receptacle, causing the Control Pilot pin to be electrical disconnected from the vehicle.

Using some mechanical relays, we can manually trigger these events and simulate a physical disconnect (end charging session), and a reconnect (start charging session).

Using some off-the-shelf components, we can manually interfere with these signals without making changes to:

- The property manager’s charging equipment
- The vehicle

Tesla offers a J1772 -> Tesla adapter with the vehicle. For this experiment, we’re going to add a Lectron Tesla to J1772, and an additional J1772 -> Tesla Adapter. We can disassemble the Lectron adapter to get physical access to the signals. Physically cut the Charge Pilot and the Proximity Pilot wires, and use some Wago Lever Nuts to run the incoming and outgoing wires outside of the handle enclosure. For a proof of concept, I used some inexpensive SainSmart 2-channel relay modules and an Arduino Uno. Both signals, under normal operation are “normally closed" so I wired them accordingly on the mechanical relays. When the relay IN signal is toggled high, the relay will latch from normally closed to normally opened. This will electrically disconnect the wires to an open circuit.

To replicate the behavior of disconnecting and reconnecting the car I do the following:

- Break the Proximity Pilot connection (simulates pressing the button)
- Break the Charge Pilot connection (simulates removing the plug from the car)
- Natural delay (couple of seconds)
- Establish the Proximity Pilot connection (simulates releasing the button)
- Establish the Charge Pilot connection (simulates connecting the plug to the vehicle)

For timing, I used the built in millis() function, where every 1000 millis was 1 second. After 13,500 seconds, 3 hours 45 minutes (some buffer for crystal manufacturing tolerance), I would kick off the above routine. Using iOS shortcuts, I automated the "Start Charging" sequence on the app which will restart the charging action after re-establishing those pins to the car.

The upfront cost for this solution is:

$50 for the J1772 -> Tesla Adapter

$160 for the Lectron Tesla -> J1772 Adapter

$14 for 2-Channel solid State Relay

$20 for an Arduino Micro.

Although this has an upfront cost of $244, the breakeven cost is 8 charges and ~ 2800 miles of charging, approximately 2.5 months at a typical 13,500 miles per year pace.

Result:

Using this device, a user can circumvent inconvenient EV charger pricing models with physical signal injection. This allows the user to sleep uninterrupted throughout the night, while saving ~ $100 / month in charging costs.

A bigger conversation:

Hopefully workarounds like this will start the larger discussion about EV charging habits and inconvenient pricing structure. If a user was restricted to charging in 4 hour blocks during daytime hours, when convenient to disconnect, you end up having many more charging sessions among vehicles with inefficient gaps between vehicles or sessions. This is not an efficient way to allocate limited assets such as EV chargers. The chargers are usually available all night because most people are not willing to pay the $35 "fine / penalty" for not waking up in the middle of the night, despite the low demand / utilization.