Design and Simulation a Solar Golf Cart for use in St. John's, Newfoundland

Abhinav[1], Sahil Kumar[2], Sahibjeet Singh Bangar[3], M. Tariq Iqbal[4]
Faculty of Engineering and Applied Science
Memorial University of Newfoundland, Canada
abhinav@mun.ca[1], sahilk@mun.ca[2], ssbangar@mun.ca[3], tariq@mun.ca[4]

***Abstract*—This paper introduces a solar-powered two-seater golf cart designed for St. John's, Newfoundland. We model it using HOMER PRO and MATLAB/Simulink, considering the PV generation, BLDC motor operation, battery dynamics, MPPT, and speed control. The economic analysis assesses component cost-effectiveness. Power surge protection and control design are also discussed. Additionally, the study extends practically to the Bally Haly Country Club's 18-hole golf course, featuring a Morphorn BLDC motor (1800W), Sharp 250W solar panel, and Discover 24V 110Ah battery system with 1 panel and 3 batteries, demonstrating the system design and simulation.**

***Keywords*—Electric vehicle design, dynamic modelling, solar EV, solar automobile, Safety Analysis and MPPT**

I. Introduction

Solar energy is a renewable type of energy that can be both limitless and clean, as well as free and environmentally sustainable. Due to this, it is attractive and has no negative environmental impact. The full adoption of transportation infrastructure powered by renewable energy is necessary at the current stage of global warming. It has been challenging to guarantee their long-term durability in a widespread deployment, nevertheless.

The global demand for energy is increasing with population growth and economic development. As a result, Governments and public institutions are increasing manufacturing and production of electric vehicles (EVs), which will bring more models to the market. Carbon dioxide (CO2) emissions from transportation and fossil fuels are a major contributor to global warming. In some way, renewable energy sources have been emphasised as a possible technology for the transportation business as well as the EV industry. A DC/DC charge controller, battery banks, PV panels and DC motor load are the main elements of solar EV system. The deep-cycle battery is charged primarily by the PV panels, extending the life and usability of the system [2].

For use in St John's, Newfoundland, we have suggested a design for a solar golf cart in this paper. There are several golf courses in St. John's, mostly 18 holes. The biggest is Pippy Park Golf Course. The best and most popular is Bally Haly country club. The terrain is hilly so more power will be required for easy commute between holes. We will be designing a 2-seater golf cart which will be powered using solar power. We will be using HOMER for sizing and design of the golf cart and simulating it in MATLAB.

II. Literature Riview

In order to begin design of a solar golf cart, we first gathered information from many documents. Many alternative solar cart designs have been created, and many analyses have been done from batteries to carbon footprint reduction. M. Tariq Iqbal et. al. used Homer Pro software was to simulate and size the mini solar EV system. Using the PV generation, battery charging, power factor correction, speed control of the electric vehicle, and DC-motor operation, a system analysis of the tiny solar EV was developed in MATLAB. In this paper to run a micro solar EV 3 PV modules were used that were 20V, 150W covering 30 km range. The model was based on 3 different factor-first, the PV modules installed on top of vehicle. Second, the PV module charging capacity and the external AC supply. Third, a DC motor spinning both forward and backward.

N. Trivedi et. al. [4] addresses the system architecture of a golf cart outfitted with four 320 W solar panels. And each panel has 45V of open circuit voltage. A series connection between the panels results in an open-circuit electrical voltage of 180 volts. This golf cart has 6 seats which operate on 48W and has battery of 160Ah. Two 48 V, 80 Ah Li ion batteries are linked in parallel to boost battery life and operability. For reducing the weight flexible panels are used. MATLAB simulation of a solar charge controller with MPPT is performed.

J. Fan describes a golf cart that is operated with lead-acid battery bank which is charged by solar current, panels instead of AC supply to, reduce CO2 and conserve power. The capacity of 420Wp solar PV panels is used and the cart power is a 3kW DC motor, 48V. To collect the data 6 input channels are used which are interconnected with 2 voltage divider, pyranometer and 3 current clump meters. In this 2-seater golf cart is tested on a golf club under different weather conditions to check its performance. The golf cart was operated in 6 sessions in 2 days. The battery's time span was raised by 4 after testing. All the testing was done with speed below 25km/h.

The article by A. F. Tazay shows the results of testing and performance evaluations of an electric golf cart fitted with a 100W solar panel, focusing primarily on mathematical equations and temperature impact while ignoring the gathering of solar resource data. The monocrystalline solar PV panels were used because of its advantages. Matlab/Simulink software is used to develop system with MPPT algorithm. For better working condition temperature was considered between 15°C and 35°C at a particular location. A deep-cycle battery is employed instead of a typical SLI battery. The 36V, 2 hp DC motor powers the solar cart with 12V sealed lead acid batteries. According to the paper its environmental data conclude that solar system may reduce 420 Kg carbon footprint.

Tariq Iqbal et. al. presents design of a small solar electric vehicle using HOMER PRO. Geographical location along with system components are considered while designing the solar electric vehicle. Vehicle is designed considering load of 3 passengers. Average commuting distance of 30 km is taken for load profiling using HOMER PRO. Kyocera KD 145 SX-UFU solar panels are used as they are highly efficient and have a low temperature coefficient. A battery storage system of 1 kWh 24VDC is chosen.

III. SYSTEM DESIGN

Here, we will provide a rough concept for the solar golf cat that will be created as a component of this work. First, we selected a location for the solar golf cart. This is done in order to use the area-specific solar irradiation data for the selected region. Then, the main components that will be utilised in the creation of a solar golf cart. Next, we would size our solar golf cart using HOMER Pro, a solar powered system design tool.

A. Site Selection

We design a solar golf cart for usage in St. John's, Newfoundland, in this study. In St. John's, there are numerous 18-hole golf courses. The longest is Pippy Park Golf Course, which is 6 kilometres long. Bally Haly Country Club is the greatest and most popular. Because the terrain is mountainous, more power will be necessary to go between holes easily. Figure 1 below shows the google maps view of the selected golf club, here in Newfoundland.

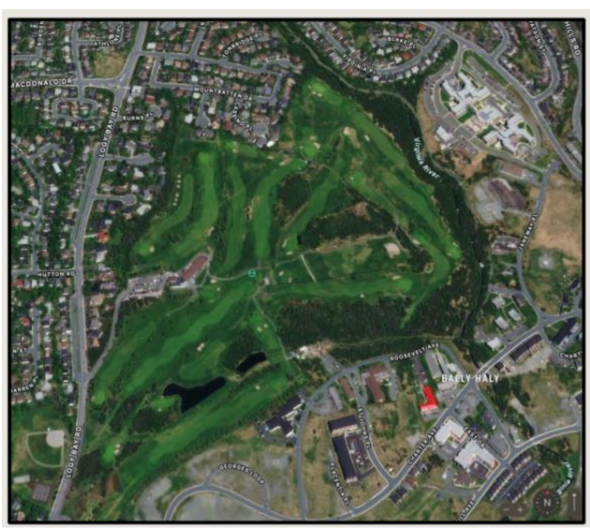

Figure 1: Location –Bally Haly Country Club

B. Load for the Solar Golf Cart

Golf Cart per day energy use over a specific distance is required to develop a load profile for HOMER Pro. We assumed that our vehicle would go 20 km per day, which is the typical distance covered by a golf cart.

Motor Power: 1800 W To be driven for 20km, that will be two 18-hole games, driving time will be 1 hour in a day.

Therefore, daily energy consumed will be: 1800 * 1 = 1.8 kWh

Figure 2 shows a typical golf cart that is used here in St. John's, Newfoundland.

Figure 2: Vehicle selection for solar system design

C. Solar radiation of Selected Site

The sun radiation and temperature data for St John's are acquired from NASA's Prediction of Worldwide Energy Resources using Homer Pro. The Scaled annual average is 3.15 kW/m^2/day as shown in figure 3 and figure 4 below.

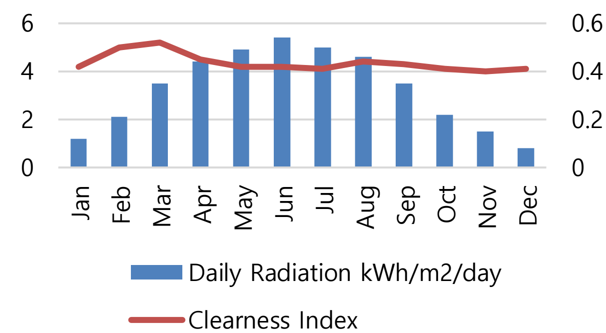

Figure 3: Solar Radiation Data

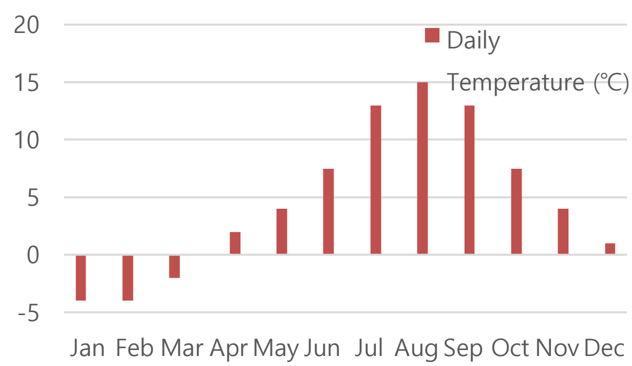

Figure 4: Temperature Data

D. System Design

In order to conduct a thorough technical and economic analysis of the system and to suggest a workable solution for the work, we used HOMER Pro. The system design utilizes of 250W Sharp solar panels generating 2.41 kW at peak, with a 1.80 kWh/day load. To store excess energy and ensure uninterrupted power, a Dis2.8 battery is used in sizing. Figure 5 below shows a homer block diagram.

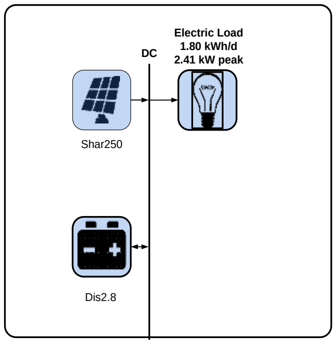

Figure 2 Schematic Diagram

The golf cart, equipped with a 1800W Mophorn BLDC motor, has a maximum speed of 20 km/hr and accommodates two people. It operates with a single solar panel and is powered by three batteries. The golf cart operates on a 24V battery system with one battery capacity of 110 Ah, ensuring sufficient power for extended use. More details are provided in figure 6 below.

Component	Specification
Maximum speed	20 kms/hr.
Passenger capacity	2 persons
Mophorn BLDC motor	1800 W
Solar panel	Sharp 250 W
Battery	Discover 24V 110 Ah
Number of solar panels	1
Number of batteries	3
Cost of BLDC motor	$200
Cost of solar panel	$369
Cost of 3 batteries	$9924

Figure 3: Golf Cart Specification in Homer Pro

E. Battery Selection

When the sun doesn't produce enough solar power, our electric automobile needs a battery storage system to maintain a steady supply of electricity. So, 3 batteries are used. The name of the battery Is Discover AES 2.8kWh 24VDC and the specification is given below:

- Nominal capacity (kWh): 2.64
- Nominal voltage (V): 24
- Roundtrip efficiency (%): 95
- Nominal capacity (Ah): 110
- Max charge rate (A/Ah): 1
- Max discharge current (A):600
- Max charge current (A): 110

F. Solar Panel Selection

In order to meet our load requirements, we installed solar panels, a sustainable energy source. The solar panels used in the project is SHARP ND-250QCS and its details is given below:

- Panel type – flat plate
- Abbreviation – Shar250
- Rated Capacity – 0.250KW
- Temperature Coefficient - (-0.4850)
- Operating Temperature – 47.5°C
- Efficiency – 15.3%
- Manufacture – Sharp

IV. SIMULATION RESULTS AND DISCUSSION

Electrical dynamic modelling is an important component of research, and this dynamic model will let us simulate the system under different conditions that a solar golf cart would experience while operating. Figure 7 below shows a part of Simulink model.

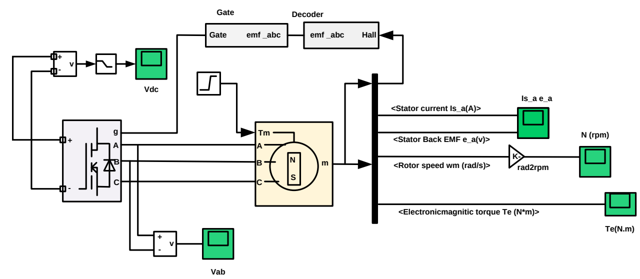

Figure 4: MATLAB Simulink model of Solar Golf Cart

The block diagram of system is given below in figure 8.

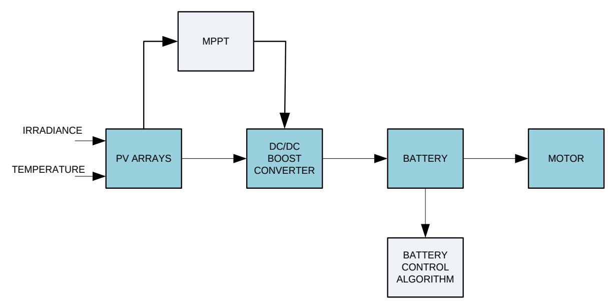

Figure 5: Block diagram

For the design of solar golf cart, we employ numerous electrical components and construct the input and output waveforms with MATLAB software for the solar golf cart. In this work, we utilize the BOOST Converter to step up the input voltage with load sides. The boost converter is linked to the photovoltaic panel, which consists of one module string and one parallel string.

Maximum power point tracking (MPPT) is an algorithm used in photovoltaic (PV) inverters to continuously modify the impedance encountered by the solar array in order to maintain the PV system's operation at, or relatively close to, the peak power point of the PV panels under different conditions, such as changing solar irradiation and temperature. Figure 9 below shows some detail of Simulink model.

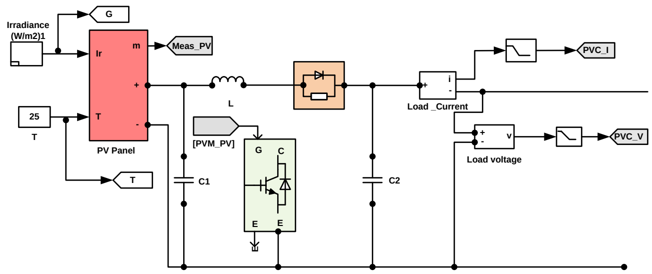

Figure 9: Matlab Simulink Model for PV connection to Solar Cart

When the battery has been regulated by an algorithm, it may be controlled by a command, which prevents thermal harm and unknown damages. You can imitate a no-isolated converter with two switching devices, an isolated converter with six switching devices, or a dual active bridge converter with eight switching devices by employing a bidirectional DC to DC converter. MATLAB software was used to implement all circuits as shown in figure 10.

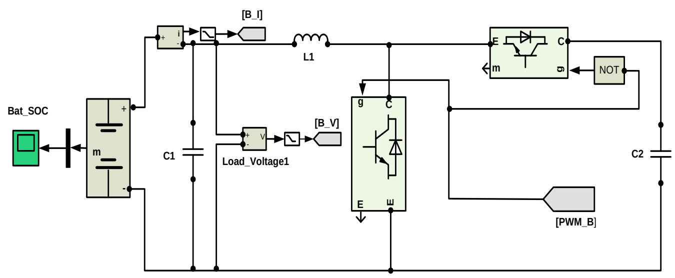

Figure 10: Matlab Simulink Model for Battery connection to Solar Cart

In this scenario, we are performing the simulation in Matlab, and the results are as follows.

A. Battery Voltage and Current Output

The battery voltage and current results over a 4-second duration is shown as below:

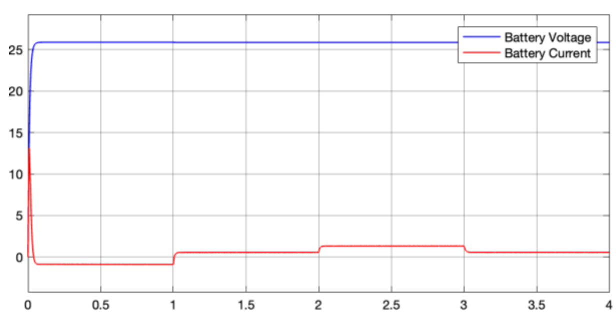

Figure 11: Battery voltage and Battery current

It starts at 0V and experiences an abrupt increase to 26V at 0.1 seconds, maintaining this voltage level for the subsequent 4 seconds. This graph visually represents a rapid change in voltage followed by a sustained period of constant voltage.

B. Battery Discharge Rate

As the batter is being used, it’s being discharged over the time period. The system's battery discharge initiates from a 50% charge level, surging for a brief second, followed by a gradual decline over the subsequent three seconds.

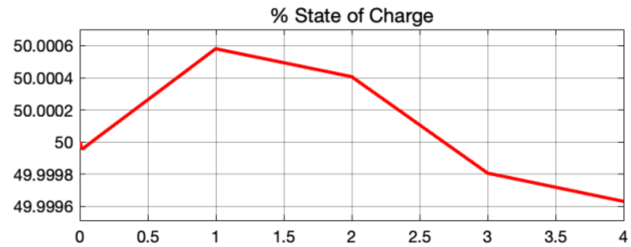

Figure 12: Battery Discharge Rate

C. Solar Panel Voltage and Current Output

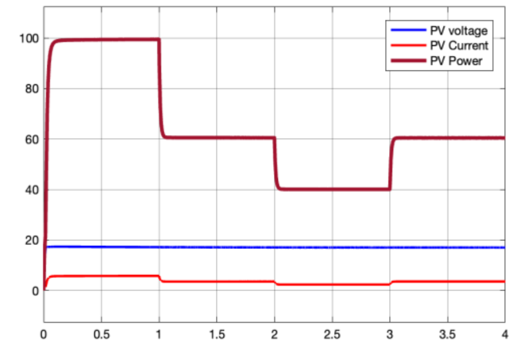

Figure 13: PV Voltage and Current Output

The behavior of the solar PV panel unfolds as follows: It starts with a voltage increase of 19 volts, maintaining this level for the subsequent 4 seconds. Meanwhile, the current experiences a slight initial surge but then remains relatively constant with minor fluctuations. In terms of power output, it surges to 100W and remains constant for 1 second, after which it decreases to 60W and holds steady for another second. Subsequently, it decreases further to 40W, remaining constant for an additional second, and then experiences a 10W increase during the following second. More details are shown in figure 13.

D. Motor rotor speed and Torque

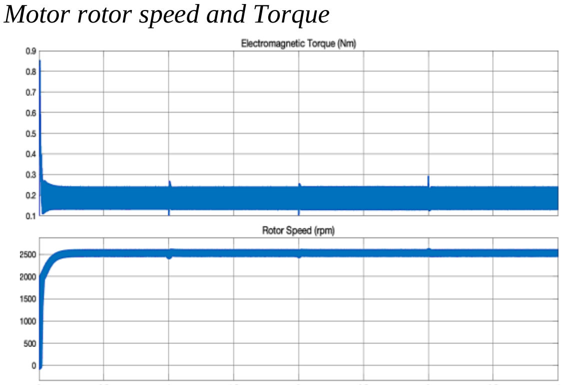

Figure 14: Rotor Speed and Torque

As we traverse a level road with no braking or acceleration in the golf cart, the electromagnetic torque remains constant, ranging between 0.1 and 0.3 Newton-meters. This torque variation does not impact the rotor speed, which maintains a steady 2500 RPM throughout the journey.

E. System Voltage and Current Output

The simulation results reveal that the output power from both the PV converter and the battery converter remain almost identical for a continuous 4-second duration. During this time, the load voltage also remains constant. However, the load power exhibits fluctuations, ranging from -30 to 10, followed by a subtle variation. Subsequently, it transitions into a step function behavior, further demonstrating the dynamic interplay between the various components of the system as shown below in fgure 15.

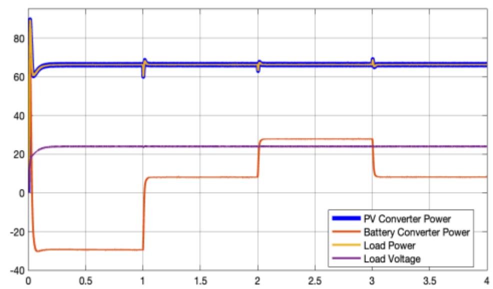

Figure 15: Converter Output

V. SYSTEM CONTROL DESIGN AND ANALYSIS

Here is the design of our golf cart in MATLAB. We have used MPPT Algorithm, battery control algorithm and algorithm for speed control. We have used pulse width modulation to give input signals for both the MPPT Algorithm and Battery Control Algorithm. The solar panel can operate at its maximum power point, or more accurately, at the ideal voltage for its optimum output of power, owing to the MPPT or "Maximum Power Point Tracking" controls, which are significantly more sophisticated than PWM controllers. Based on the voltage and voltage of the connected solar panel, MPPT Solar Charge Controllers can be up to 30% more efficient. When using two or more solar panels or when the panel voltage (Vmp) is 8 volts or higher than the battery voltage, MPPT charging controllers can be used. The INC Algorithm was employed in this case as shown in figure 16.

Our solar golf cart uses a BLDC motor in this instance. The BLDC motor has a good speed range, great torque, and excellent efficiency. Hall effect sensors are used to regulate the speed of the BLDC. Hall effect sensors operate the motor by detecting the position of the rotor. Trapezoidal control, also known as trapezoidal pulse-width-modulation (PWM) wave, is the driving method. The proportional-integral (PI) controller is used to control the rotation speed.

We use switching circuits and control circuits to control the motor in the driving system of BLDC motors. Because the rotor locations will determine the motor's direction, this controller need them as feedback. Electronic Speed Controller is yet another controller utilised in this vehicle (ESC). It is a gadget that uses power electronics components to regulate the motor's speed. The term "variable speed drive" is well-known.

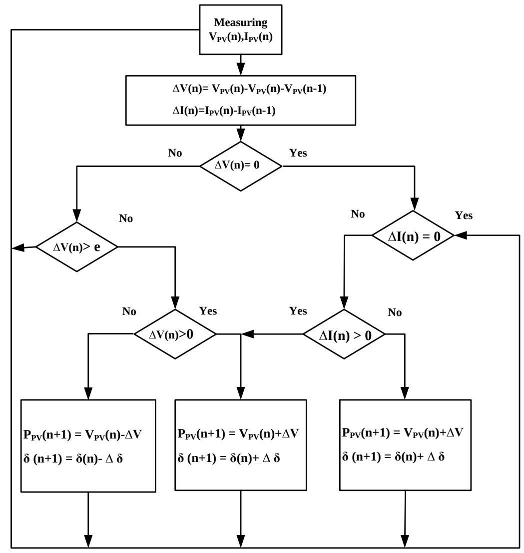

Figure 16: INC Algorithm block diagram

VI. CONCLUSION

For the Bally Haly golf course, a two-seat solar-powered golf cart has been designed. The testing environment is similar to how a typical golf cart operated by golfers would actually function. According to analyses of the data in this study, a golf cart with a 250 W solar PV system installed can generate enough electricity throughout a day of good weather to operate the cart.A solar cart reduces CO2 emissions in addition to saving energy and extending the life of batteries.

It may be said that a solar-powered cart is practical from a technical, financial, and environmental standpoints. The payback period for installing a PV system on a cart will surely be shorter as the cost of solar PV modules declines and the cost of fuel rises.

REFERENCES

[1] K. M. v. s. aashish joshi, ""Electric Vehicle Charging Station," vol. 8, no. 4, pp. 122-128, 15 july 2021.
[2] A. F.Tazay, "Design and Implementation of Solar Powered Electric Vehicle for on campus University Application," vol. volume 14, pp. 920-927, 2021.
[3] A. H. M.Tariq Iqbal, "Dynamic Modeling of a Micro Solar Electric Vehicle for Pakistan using Simulink," IEEE, St John, 2022.
[4] N. Trivedi, N. S. Gujar, S. Sarkar and S. P. S. Pundir, "Smart Solar Charge Controller for Electric Golf Promoting Green Transportation," IEEE, Pune, India, 2018.
[5] J. Fan, "Solar Powered Golf Cart: Testing and Performance Analyses," IEEE, Singapore, 2018.
[6] A. H. M. Tariq Iqbal, "System Design and PV Sizing of a Micro Solar Electric Vehicle for Pakistan," IEEE Conference on Technologies for Sustainability (SusTech), 2022.
[7] "Generic battery model - Simulink." https://www.mathworks.com/help/physmod/sps/powersys/ref /battery.html
[8] "Constant-current constant-voltage battery charger - Simulink." https://www.mathworks.com/help/physmod/sps/powersys/ref /cccvbatterycharger.html
[9] A. Sierra and A. Reinders, "Designing innovative solutions for solar-powered electric mobility applications," Progress in Photovoltaics: Research and Applications, vol. 29, no. 7, pp. 802–818, 2021, doi: 10.1002/pip.3385.