2023-2024 FSGP AND ASC SOLAR CAR COMPETITIONS MULTI-OCCUPANT VEHICLE SCRUTINEERING, CHARGING, AND ENERGY METERING



IEF Solar Car Conference, 01/28/23





Presented By Head IEF MOV Inspector

Evan Stumpges <<u>evan_stumpges@americansolarchallenge.org</u>>

MOV AGENDA TOPICS

Energy Metering Charging Scrutineering **Open Discussion, Q&A**

THIS CONTENT IS INTENDED TO SUPPLIFIE **REGULATIONS BUT DOES NOT SUPERSEDE THEM** DISCLAIMER

MOV METERED CHARGING HISTORY

- Why metered charging?
 - MOVs aren't regulated on battery weight.
 - practicality features
 - > Assessing MOV teams as though they fully charged their battery from empty any time they plug in is not accurate or fair
 - Previous ASC/WSC regs severely penalized topping off the battery pack with partial charges
 - Previous ASC/WSC regs encouraged starting the last competition day with a full pack even if not needed to finish the event
 - > Enabling metered charging allows teams to benefit from partial charges to gain more control over their scoring formula
 - > Before metered charging was implemented there was no real incentive for MOV teams to utilize solar charging hours
- > Why did it take so long to implement charge metering?
 - It took time to reach agreement on the following:
 - > Developing a solution to accurately monitor charging energy at different voltage/current levels across all MOV teams

 - Ensuring that teams won't be able to bypass the charge meters during the event

> This allows teams the flexibility they need to appropriately size the battery to support their vehicle's number of occupants and

Standardizing teams on the J1772 EV charging protocol and defining minimum safety requirements for metered charging > Determining where in the charging circuit the energy monitoring would be placed (DC vs On-board AC vs Off-board AC)

MOV METERED CHARGING REQUIREMENTS

- - > <u>Note</u>: vehicles designed to use a different standard EV connector may use an adaptor cable provided it is carried in the vehicle and doesn't exceed 1m in length
 - their vehicle to an energy source for charging during the event
 - EVSE equipment does not need to be carried inside the solar car

 - as a solution for charging from a portable generator if necessary
- with an adjustable current limit to charge the battery
 - chassis if it contains any exposed metal

Securely mounted J1772 (Type 1) vehicle power inlet receptacle and compliance with the SAE J1772 EV charging protocol

> Team must provide their own Level 1/Level 2 J1772 Electrical Vehicle Supply Equipment (EVSE) in order to connect

Event organizers are not responsible for providing external energy sources or adapters for teams to use

It is recommended for teams to carry a variety of adapters to use their EVSE with common electrical outlets as well

> Teams are allowed to use commercially available J1772 charging stations if they can find them during the event

Rigidly mounted onboard charger that accepts external energy from a 120-240Vac power source and outputs DC power

> The vehicle power inlet ground connection must connect to the charger's AC input ground and be tied to the charger

> The charger's AC input and DC output must be electrically isolated from each other as well as from the vehicle chassis

MOV METERED CHARGING REQUIREMENTS

- vehicle power inlet and the onboard charger's AC input
 - Meter connections will be NEMA 14-50
- Dedicated power port and charger relay for the battery box that is utilized only for external energy charging
 - Charger power relay must be open whenever the vehicle is in "Safe State" per regulation 8.3.A.9
 - > All exposed connectors/conductors on the AC/DC charging power lines between this battery box port and the J1772 vehicle power inlet must be enclosed in an approved manner that can be locked/sealed by the Event Organizers to prevent any of these connections from being unplugged or tapped into to bypass the energy meter or the J1772 power inlet
 - > The team must also provide a way to seal their charger to prevent unauthorized access to its internal components
- Charging Safety Features
 - > Any covers for AC or DC power connections must be nonconductive, marked with "Caution: High Voltage", and only removable with the use of tools
 - > All conductors used for MOV charging must be appropriately sized to carry the vehicle's maximum possible charge current When a J1772 plug is connected, the vehicle must automatically prevent the use of the drive motors

 - > When charging from an external energy source the BPS must always actively monitor the battery state and the MOV charger must be isolated during a BPS fault

Accommodations for an onboard AC energy meter provided by the Event Organizers that will connect inline between the

MOV METERED CHARGING REQUIREMENTS

No Internal Access to Meter Enclosure

- IEF Meter Mounting
 - Teams are not allowed to drill holes into the energy meter enclosure

 - Straps are acceptable to use around the enclosure
 - Open to other ideas for mounting
- The display of the meter needs to be visible to be read each day
 - at the start and finish of each charge throughout the event

Teams are not allowed to break the tag and open the energy meter enclosure

3M Dual-Lock or similar is acceptable to use on the bottom of the enclosure

Teams must take photos with time stamps to document the energy meter reading

IEF Energy Meter Info

- This onboard energy meter will be provided to MOV teams by IEF
- The meter must be installed in the solar car during Scrutineering
- EKM Omnimeter Pulse v.4 meter provides revenue grade accuracy
- Flexible 120-240 Vac input voltage at up to 40A current
- Watertight enclosure with sealed cable glands
- ~\$500 cost for this charge meter solution
- The energy meter can be reserved in advance of the event in exchange for a \$500 deposit payment from the team and the cost of shipping
 - The \$500 deposit is refundable after the meter is returned to IEF
- Teams can construct their own energy meter using the reference BOM below

Item	QTY	Un	it Cost	To	tal Cos
EKM Omnimeter Pulse v.4 – Universal Smart Meter	1	\$	260.00	\$	260.00
EKM Split-core CT, 200A Current Transformer	2	\$	45.00	\$	90.00
EKM Watertight Enclosure with Hinged and Latching Lid (6.7" x 10.63" x 4.33")	1	\$	80.00	\$	80.00
Camco 55215 18" PowerGrip Extender - 50 AMP	2	\$	19.95	\$	39.90
Marathon Special Products 1414300 Splicer Block, 4-P, 115A, Line: 2AWG-14AWG	1	\$	18.08	\$	18.08
Waterproof Cable Gland (2pc Set)	1	\$	10.05	\$	10.05
Total				\$	498.0

Meter BOM Reference

J1772 to NEMA 14-50 Wiring

Voltage Sensor Reference

How to Integrate kWh Meter Onboard Solar Car

MOV solar cars must feature an inline NEMA 14-50 connection between the J1772 Vehicle Power Inlet and the Onboard Vehicle Charger. When not at an ASC/FSGP event, the NEMA 14-50 connectors will be directly connected as shown below.

Meter Display Cycle

Total kWh Energy

L2 Amps

When the team comes to an ASC/FSGP event, they will disconnect the NEMA 14-50 connectors and plug them into the kWh Charge Meter as shown below. The NEMA connectors will be sealed together for the duration of the event so the meter can't be bypassed.

The kWh hour meter is watertight, weighs 6lb, and has enclosure dimensions of 11" L x 7.5" W x 4.5" H with a connector to connector length of 27".

MOV CHARGING QUESTIONS/DISCUSSION

- chargers or EVSE?
- Does your EVSE disable charging if there is a broken AC ground? If so, is there a way to bypass and still allow charging?
 - Some EVSE doesn't offer broken ground detection while others warn or disable
- Any teams have issues using their EVSE with a portable generator to charge?
 - Many portable generators have floating grounds which can cause EVSE to fault out due to ground fault protection
 - This can usually be overcome with a special adapter that bonds the neutral to ground
- Are any teams planning to design/build their own custom onboard vehicle charger?

> Any teams interested in sharing good/bad experiences with their onboard vehicle

IMPOUND IN VEHICLE

- vehicle for impound purposes
- In that case they must provide alternative and reliable means of securing the batteries to prevent any unmetered charging of the batteries during impound hours
 - MOV impound state must lock access to the battery box lid(s) and any air inlets/outlets that could allow access to high voltage connections, as well as any power connections to the motor, solar array, etc
 - > MOV battery enclosures must not contain any externally accessible hinge/latch hardware
 - > A maximum of 4 seals can be used on a regular basis by teams to impound or un-impound
 - In impound configuration the metered J1772 power inlet must be the only functional/ accessible battery power connection
- Failure to properly impound during the designated hours at the Event will result in a full unmetered external energy charge being added in the team's Score.

Multi-Occupant vehicles are exempt from the requirement to remove the batteries from the

IMPOUND CONSIDERATIONS

When is it OK for an MOV team not to impound?

- Any time an MOV team fails to properly impound during the designated hours they will be assessed a full unmetered external energy charge in their Score
- Any time an MOV team elects to charge from unmetered external energy they must officially declare this intention to event organizers (and observer during the Tour)
 - MOV teams that have indicated they will be charging from unmetered external energy overnight do not need to impound that night
- Why might a team choose to conduct unmetered charging?
 - Failure to gain certification for metered charging during Scrutineering
 - Vehicle is missing or has nonfunctional onboard charger, J1772 receptacle, EVSE, etc.
 - Vehicle design is unable to accommodate the onboard IEF energy meter
 - Vehicle doesn't satisfy metered charging impound/safety/lockout requirements
 - Battery pack is drained and solar evening/solar charging is not viable so team decides it is more beneficial to accept the full unmetered external energy charge and bypass the efficiency losses of their onboard charger

ASC 2022 MOV SCRUTINEERING SHEETS (REFERENCE)

ASC/FSGP 2022 SCRUTINEERING (July 2022)

TEAM:

MOV Station p1

#

TEAM:

	-
8.10.A Charger	Result/Comments
Onboard vehicle charger rigidly secured in vehicle	□Pass □Fail
Charger protected from water ingress	□Pass □Fail
Charger able to accept input voltages from 120-240 Vac	□Pass □Fail
Charger power rating (kW)	
Charger DC current request methodology (describe)	
 Considers max battery DC charge current limit from BMS 	□Yes □No
 Considers user set max AC or DC charge current limit 	□Yes □No
 Considers the J1772 control pilot max AC current limit 	□Yes □No
 If possible, describe how AC current is regulated to the J1772 control pilot max and/or how the AC current limit is translated to the DC current limit 	
8.10.B Vehicle Power Inlet & 8.10.C Charging Adapter	Result/Comments
Standard EV power inlet receptacle present	□Pass □Fail
Vehicle power inlet securely mounted to vehicle	□Pass □Fail
Adapter needed for J1772 plug to another standard EV power inlet	□Yes □No
 Charging adaptor isn't longer than 1m in length 	□Pass □Fail □N/A
 Charging adapter carried in vehicle when not in use 	□Pass □Fail □N/A
8.10.D Energy Metering	Result/Comments
IEF energy meter assigned to team (Meter #)	
Vehicle features NEMA 14-50 inline connection for energy meter	□Pass □Fail
Energy meter display location is can be visibly read while charging	□Pass □Fail
Charger is sealed to prevent unauthorized internal access	□Pass □Fail
Battery box features dedicated charger power port and relay	□Pass □Fail
8.10.E Charging Safety	Result/Comments
BPS is actively monitoring/protecting the battery during charge	□Pass □Fail
When the Main Power Switch controlled by the BPS opens, the output of the MOV charger disconnects from the battery pack	□Pass □Fail
Onboard charger current is automatically limited by the BMS as battery approaches full charge to avoid BPS faults	□Yes □No
AC/DC power connection enclosures/covers	Remarks Remarks Sales
 Non-conductive 	□Pass □Fail
 Only removable with the use of tools 	□Pass □Fail
 10 mm high letters with "Caution: High Voltage" 	□Pass □Fail
Power conductors sized appropriately for max AC/DC currents	□Pass □Fail
 AC power min conductor size (AWG) 	
 DC power min conductor size (AWG) 	
8.10.F Electric Vehicle Supply Equipment (EVSE)	Result/Comments
Team has J1772 EVSE	□Pass □Fail
EVSE can be plugged into standard NEMA 5-15 120Vac outlet	□Yes □No
120Vac compatible (list max current in A)	□Yes □No
240Vac compatible (list max current in A)	□Yes □No
Team has a generator that can be used to charge the vehicle	□Yes □No

Batter Motor Solar Other **MOV** Chargi Plug in the IEI Verify pinout Neutra Ground charge L1 (B) termir • L2 (R termir Verify charger AC in AC in DC out Have the team Have the team Proxin

ASC/FSGP 2022 SCRUTINEERING (July 2022)

MOV Station p2

	1
+	ł
ħ	r

	Té	
8.10.G MOV Impound	Result/Comments	
Solution allows main battery power connectors/conductors to be locked/sealed	□In Chassis Impound	
such that unmetered battery charging can't occur	□External Impound Box	
 Battery box lid(s) 	□Pass □Fail □N/A	
 Motor power port(s) 	□Pass □Fail □N/A	
 Solar array power port(s) 	□Pass □Fail □N/A	
 Other connector/conductor (describe) 	□Pass □Fail □N/A	
MOV Charging Testing/Metered Charging Certification	Result/Comments	
Plug in the IEF onboard energy meter in their vehicle	□Pass □Fail	
Verify pinout at the terminal block inside the meter enclosure		
 Neutral (W) - no continuity with other terminals 	□Pass □Fail	
 Ground (G) - continuity with vehicle power inlet GND & any exposed charger/chassis metal but no other terminals 	□Pass □Fail	
 L1 (B) - continuity with one of the vehicle power inlet Lines but no other terminals 	□Pass □Fail	
 L2 (R) - continuity with one of the vehicle power inlet Lines but no other terminals 	□Pass □Fail	
Verify charger power conductor isolation		
 AC input power to DC output power conductors 	□Pass □Fail	
 AC input power conductors to vehicle chassis 	□Pass □Fail	
 DC output power conductors to vehicle chassis 	□Pass □Fail	
Have the team demonstrate charging with their own J1772 EVSE	□Pass □Fail	
Have the team demonstrate charging with IEF J1772 EVSE	□Pass □Fail	
 Proximity Pilot Validation 	□Pass □Fail	
 Control Pilot Validation 	□Pass □Fail	
Verify the IEF onboard energy meter is reading correctly	□Pass □Fail	
Vehicle drive motor is disabled when a J1772 plug is connected	□Pass □Fail	
Vehicle charging system is able to detect and prevent charging in a broken AC ground scenario	□Yes □No	
Lock/seal all exposed connectors/conductors on the AC/DC charging power lines between this battery box port and the vehicle power inlet to physically prevent any of these connections from being unplugged or tapped into	□Pass □Fail	
Battery Pack Capacity in kWh from Electrical Station [Q]		
Vehicle certification for metered charging in this event	□Certified □Not Certified	

Station Manager:	
Entrance:	Fully assembled car & Electric Vehicle Supply Equipment (EVSE) Yellow status or better in Electrical and BPS.
Station Grade:	Green = Pass Blue = Pass/Penalty Yellow = Not available at this station

Red = Fail / Safety Hazard

SCRUTINEERING LESSONS LEARNED

- > Before the event please test that your vehicle's drive motors are automatically disabled whenever the J1772 charge plug is connected to the vehicle
 - Failing this test is one of the few ways to get a red status in the MOV station.
- > Design your battery box with a dedicated charger relay that is linked in with the BPS trip circuit
 - > When the car is in safe state both + and charger connections must be isolated from the battery
 - The charger relay should only be enabled during charging
- Consider adding the ability for the driver to manually set a lower charge current limit than the BPS and EVSE will allow (have yet to see this feature in an MOV)
 - > This could come in useful if you are you are overheating your onboard charger or overloading an electrical circuit breaker at full current
- Test your solar car charing system at a public Level 2 charging station before the event
- Test charging your solar car using your EVSE and a generator before the event

SCRUTINEERING LESSONS LEARNED

- We recommend bringing adapters for common 120V and 240V receptacles
 - Never charge charge with the AC current limit above 12A using a NEMA 5-15 (120V, 15A) plug
 - the charge current setting
- throughout the event
- before you come to the event
 - Ensure that all power cables in this circuit are accessible to be visually inspected during Scrutineering
 - Try to minimize the number of seal tags required (especially for seals that must be regularly removed for impound, etc)
 - between needing to be charged
 - station
- preventing access without significantly blocking airflow)

> Be very careful when using charging adapters never use a 120V plug/receptacle in an AC circuit running at 240V and ensure that the connectors/wire throughout the charging circuit (utility receptacle, EVSE/adapters/extension cords, and vehicle wiring) are rated for

> Ensure that the IEF energy meter will fit in the vehicle and can be mounted such that it's display will be visible to collect readings

> Please think carefully about security/sealing the charging circuit (from Vehicle Power Inlet to the Battery Box) and impound sealing

> If seals must be broken to change or charge your supplemental battery pack try to ensure that the pack will last at least one day

Figuring out sealing solutions on the fly during Scrutineering will significantly increase the time it takes to get through the MOV

For teams sealing their onboard chargers inside an enclosure please be sure that your charger heatsink/fans will have good access to airflow to prevent overheating (we've seen successful use of mesh screens secured from the inside of the enclosure as a means of

METERED CHARGING LOCKOUT LOCATIONS TO BE INSPECTED

In order to be certified for metered charging, MOV teams must provide acceptable provisions to lockout access to any locations that could allow for bypassing the IEF Energy Meter.

Color Key

Provision to lockout internal access

Provision to lockout connector access

Provision to disconnect and lockout access during impound

Meter enclosure is provided locked out

Exposed conductors not allowed and must prevent inadvertent disconnection but lockout not required

J1772 is always accessible to teams certified for metered charging

