WHITE PAPER

Solar Trailers:

Considerations for their design in a mining environment

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EXECUTIVE SUMMARY

3D-P has over 20 years of experience in designing and deploying solar radio repeater solutions in mines. During this time, 3D-P has deployed solar systems in the Arctic, on the Equator, in deserts around the world, and in all places in-between. Experience proves that power outages can often be disguised as system failures in radio and camera infrastructures, and can result in expensive downtime and troubleshooting time.

Power problems should be minimised wherever possible. An initial analysis understanding the environment in which the trailer will be deployed and the specific customer's requirements should be performed. From the results of the analysis, a number of trailer components will need to be carefully selected so that they best perform at the deployment location. Through this paper, 3D-P discusses the components to carefully consider and what to avoid.

I. Correct Sizing of Solar Panel Array and Battery Bank

The selection of the solar panels and battery bank is greatly influenced by the geographical position of the trailer, the weather at its planned deployment location and the number of autonomous days required.

Accurate meteorological data is therefore required. NASA provides a wide range of historical meteorological data on weather conditions by location. This data is searchable by latitude and longitude and includes information on hours of solar coverage, average consecutive days of cloud coverage and average temperature for each month of the year at the specified location. Utilizing this data along with nominal power consumption of the devices to be installed on the trailer allows to determine the required number of solar Watts (W) and battery Ampere-hour (Ah) capacity required for a specific deployment.

For educational purposes, the following hypothetical example will be used over the next few sections:

> Mine Site B is located in the Northern part of Canada. It experiences long and cold winters with short days for a few months of the year. The system to be installed on the trailer includes a radio with a 15W nominal draw, as well as an Ethernet switch and a charge controller which have a combined 5W nominal power consumption. The combined systems to be installed on the trailer therefore have a 20W nominal draw at 24vdc and will run around the clock.
> The NASA data shows that this site only receives 2 solar hours daily on an Equator tilted surface during the month of January, which month has the lowest average daily solar hours for that site. The data also shows that the site often experiences up to 3 days of cloud coverage over a seven day period during the worst month of the year and that the coldest average month of the year is January with an average temperature of -20 deg C.

A. Correct Solar Panel Sizing

For a correct solar panel sizing, both the historical meteorological data and the nominal power requirement of all the installed systems are required.

The nominal power requirement is calculated by testing the equipment at a specified duty cycle to determine what the true power requirement is, and ensuring that the solar system is designed appropriately. For example a particular radio may have a maximum power consumption of 30W, however the nominal power consumption at 75% of the duty cycle may only pull 15W in actual use. The maximum power consumption is used to ensure the wiring and circuit breakers are appropriately designed. The nominal power consumption is used in sizing the solar system.

In our example, the system must be capable of a 20W nominal draw. The solar system to be used should therefore be able to recharge a full day 480 watt (20W*24 hours) utilization in under 2 hours of available solar radiation. Some expected inefficiencies should also be added to the power requirement. They include, among others, potential dust on the panels, their improper orientation or their ageing (all solar panels exhibit an increasingly degraded output over their expected life). 3D-P recommends to include a 25% decrease in panel capacity to the power requirement.

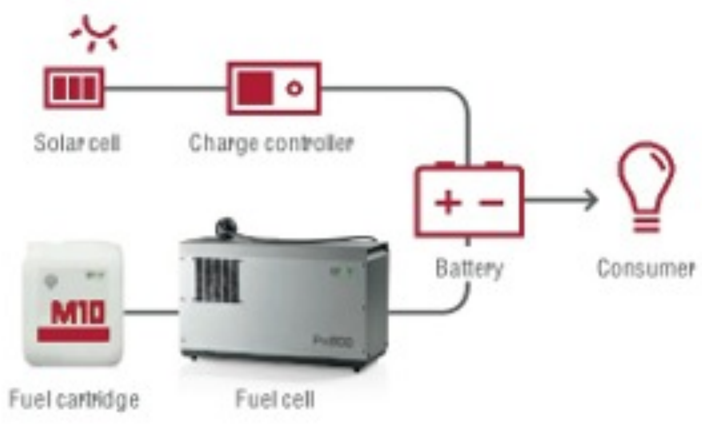
Let's consider a single 300W panel design:

- 25% decrease in panel capacity: 300W * 0.75 = 225W/solar hour
- With 2 solar hours daily during its worst month, a single solar panel would be expected to output: 225W * 2 hours = 450W/day

This would be insufficient for the required daily load of 480W, resulting in depleted batteries after only a few weeks.

- Proper performance can be obtained through a dual panel system providing 900W daily: 225W * 2 panels = 450W/hr, 450W * 2 hours = 900W

In subarctic climates, even a well designed solar trailer may require auxiliary charging in the event of an extreme cold snap or during longer than anticipated stretches of low sunlight. All on-board battery charger should be considered as an option for these regions to permit supplemental charging from an external power source. One option includes the use of a hybrid power solution combining a solar power system with a fuel cell generator. This system uses a catalytic process which converts methanol into electricity. The generator monitors the battery charge level and automatically recharges it to compensate for any sun shortfalls. It then switches to standby without any need for human intervention.



Fuel Cell Technology Principle

B. Correct Battery Bank Sizing

The battery capacity (also sometimes called autonomy) should be designed so that it provides enough power in Ah for the system to discharge to no more than 50% during the longest expected period of cloudy days. The 50% desired reservoir is designed primarily to increase the service life of the batteries, as average depth of discharge has a large effect on the lifetime of the batteries. 3D-P designs are based on a recommended battery replacement every 5 years.

The average temperature should also be taken into account when designing the size of the battery bank. In severely cold temperatures, the battery capacity of the deep cycles drastically decrease, and at -20 deg C, batteries show a nearly 50% reduction in capacity. In addition to this temperature-caused capacity reduction, the batteries can easily freeze if they are allowed to discharge completely and thawing will first be required before recharging them. This situation should be avoided in order to provide proper performance from any solar system.

In our example, the site averages three days of cloud cover in a seven day period, resulting in a three-day autonomy required. The battery bank size is calculated as follows: :

- 480W daily load at 24vdc: 480W / 24V = 20Ah daily
- Three day discharge: 20Ah * 3 = 60Ah
- 2 x battery capacity due to -20deg C temperature: 60 * 2 = 120Ah

- 2x additional desired battery bank buffer to extend battery life: 120 * 2 = 240Ah

In this example, the total battery requirement would be 240 Ah, resulting in a solar trailer design which would include two 300W solar panels and two 8D sized 265Ah deep cycle AGM batteries wired in series for 24vdc.

II. Panel Array Orientation & Deployment

A. Panel Array Orientation

The orientation of the panels greatly influences how efficiently the batteries recharge. Optimal orientation is therefore recommended.

The ideal angle is when the sun hits the panels at a perfectly perpendicular angle (90°), maximising the amount of energy produced. However, the Sun moves into the horizon throughout the day and two factors should be taken into consideration when selecting the appropriate panel angle:

- The orientation (North/South/East/West)
- The tilt angle to match the solar azimuth

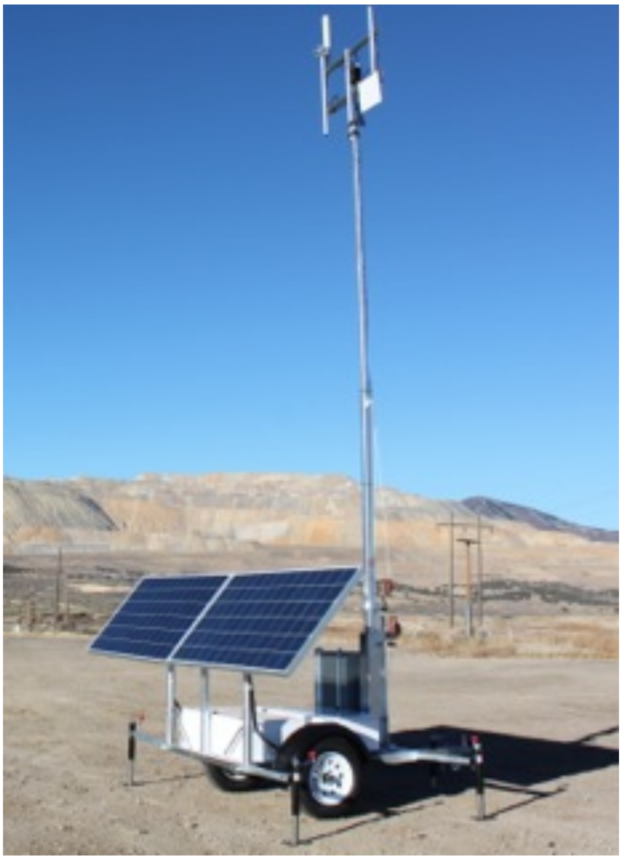
In extreme North climates, 3D-P recommends deploying the solar panels vertically to reduce snow and ice build-up.

B. Easy Deployment

In addition to their correct orientation, the panels should be easy to deploy and adjust.

Mines are not static environments. Blasting activities and advancing mining faces demand that much of the network infrastructures remain mobile. During each re-deployment, the panels must be set at the proper orientation and tilt angle, and the radios must be orientated so that the antennas provide the proper coverage angles. Moving and re-deploying the solar trailers become a frequent activity, and ease of use and accuracy are critical user concerns.

As a result, a solar trailer should have a solar panel mounting solution that allows easy rotation and tilt adjustments. The panels should also be designed to mount on the trailer in such a manner as to prevent any shadowing on the panels when deployed. Experience shows that a small shadow, such as the shadow cast by the mast of a trailer, can reduce a solar panels output by as much as 80%.



III. Antenna Mast Considerations

The installation of a manual 360 degree rotating dual winch mast is recommended in most designs as it provides additional safety and ease of deployment.

The manual dual winch ensures that the mast can be nested horizontally for trailering and deployment of radio equipment, removing the need for a truck or ladder and increasing the safety of the staff on-site. Once all the equipment is mounted and connected, the first winch is used to lift the mast to a vertical position, while the second winch is utilized to raise the mast to its full height. In addition, the manual option is often preferred to the electric winch as it has less chances of failures (including from battery failure). It also provides greater safety than an electric winch which has a lower level of self-breaking and could fall at time of raising if power was to stop.

The 360 degree rotating feature of the mast ensures the easy alignment of all the directional antennas and other devices mounted on the mast. A set screw is often used to loosen the mast so that it can be rotated by hand to the appropriate angle before the set screw is re-tightened firmly locking the mast at the new orientation.

The height of the mast also needs to be considered. Some trailer masts can only reach 10ft not allowing them to see over the MSHA berms. Experience shows that a mast height of 20 to 30ft is optimal as it reaches over the MSHA berms at the mine, while not reaching so high that the radio traffic extends far into neighboring cells which can decrease the performance of 802.11 based wireless networks.

The 3D-P Design

The 3D-P solar trailers are designed with the panels mounted at the back of the trailer. When deployed to face the sun, the mast and other trailer components are behind the panels, keeping them from ever creating a shadow on the panel.

3D-P also offers an easy solution to adjust the panels direction and tilt angles through the use of a set of screws. Their loosening allow the angle and direction of the panels to be adjusted, whilst their tightening lock the panels at any desired direction or tilt angle.

The 3D-P mast easily rotates through 360 degrees to allow proper alignment of antennas, again through the use of a single set screw.

Finally, the 3D-P mast incorporates a 2-section design for the vertical height. This design minimises the slop and play that are the result of multiple sections, resulting in a more stable mast and subsequently a more stable antenna mount. This can play a significant part in extending radio components life as well as in helping with the performance of the directional type antenna systems.

IV. The Importance of Stability

Solar trailers should include easy to deploy outriggers providing a much larger footprint than the trailer itself and ensuring a solid base.

The 3D-P solar trailers include robust and wide outriggers that retract in just a few movements for trailering.

V. Trailer Frame Quality

Many solar trailers available on the market are painted steel or aluminum. Experience shows that both options become unserviceable as early as 3 to 4 years.

An alternative option is the use of a hot dip galvanised frame in the design of a new solar trailer which prevents the early development of corrosion. Solar trailers in a mining environment are often deployed in extremely corrosive environments, such as on or near leach pads. Even when not deployed in these environments, years of normal exposure to the elements are expected, and trailers must be designed to be able to withstand this abuse. Hot dip galvanizing the trailer frame provides the greatest protection from these elements. During this procedure, the trailer frame, mast and solar panel mounts are all cut, welded and the entire assembly is then dipped in a vat of galvanizing material. This ensures that both the inside and the outside of all the steel tubing are protected from the environment. The result is a greatly extended life of the trailer over any trailer that is painted or even powder coated.

VI. Additional Considerations

Appropriate AC and DC voltages must be considered. In addition, any converters/inverters used should provide maximum efficiency and be rated appropriately for the environment.

High quality enclosures should also be used for electronics and batteries in order to prevent the penetration of water and dust. The NEMA 4 rated enclosure is recommended.

Finally, it is important to monitor the remote solar trailer for battery status, charge status, location, autonomy and charge performance over time. 3D-P uses the MPPT60 charge controller which has the capability to monitor both charge and battery status as well as historical performance. This controller has an available Ethernet port that can be connected to the radio for remote monitoring. It is recommended to check the MPPT log at least every two weeks and more frequently after an extended period of overcast.

The 3D-P Design

3D-P goes a step further by pulling this information from the trailer and adding the critical monitoring points to the network dashboard, allowing alerts, trending and data logging for each solar trailer. Depending on the capability of the radio network, the position of the trailer may also be provided via GPS. When a 3D-P Hornet is used at the infrastructure location, integrated GPS is available. Integrated GPS is also available on Rajant infrastructure devices as well as some Cisco networks.

Conclusion

To ensure best performance of solar trailers, a number of factors have to be carefully taken into account at the time of design. Poor design can lead to systems frequently down, increased maintenance and regular parts replacement.

Understanding the wide variety of options available and that not all suppliers provide the same quality, 3D-P offers through its Consultative Team a service to run a full analysis that will help its customers design a solar trailer that will best meet the specific requirements of their mine site.

Our design philosophy addresses 3 major issues - durability, ease of use and high reliability.

For more information on solar trailers or to know more about the 3D-P product, please email sales@3d-p.com.

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