Hydraulic Power Generation Unit Powered by Photovoltaic Energy

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Abstract: *The conversion of solar energy into electricity can provide a solution to the following problems: access to electricity for users or applications in areas without access to the electricity grid and hybrid system operation of some equipment in order to reduce pollution due to conventional energy sources (internal combustion engines, mainly). In both cases, if hydraulic power is required at the end user (irrigation systems, waste compaction, lifting installations, various drive systems), this is obtained with the help of an electro-hydraulic pumping unit, powered by a battery, charged with the help of a group of PV panels.*

Keywords: *Photovoltaic supply, hydraulic power unit, hydraulic drive system*

1. Introduction

A specially designed photovoltaic system can be used to provide a hydraulic power unit in hard-to-reach areas without an electrical network. It can be built in the form of a unit that can be deployed quickly in the field alongside a group of photovoltaic panels. An actuation system using a solar-powered pumping group is suitable, for intermittent use day or night that operates on the basis of the energy provided by a photovoltaic system in combination with the energy stored in an accumulator. Thus, it is not necessary to dimension the photovoltaic system to support all the power required by the hydraulic pumping group. The system described in this article can greatly facilitate the implementation of a remotely controlled actuation system for actuating a valve, some mechanism, irrigation canal gate, etc. [1,2,3]. For applications in hard conditions, which require relatively high forces (torques), a hydraulic actuation can be used, and the system can also be equipped with an automation system and remote control via GSM or LoRa modem [4]. PrimeHyd company has developed a remote control system that provides wireless data transmission in real time and allows the operation of a valve from a distance of hundreds of km for customers in the mining field all over the world [5]. Another system is a solar-powered Hydraulic Power Unit (HPU) from Shafer Valve, an Emerson Company that provides hydraulic energy for valve automation in distant regions or places lacking reliable energy sources. Solar modules are tailored to meet the required watt-hour capacity, factoring in the peak sunlight hours at the specific location. Additionally, the solar modules can be installed remotely to accommodate hazardous area applications [6].

2. The photovoltaic system

The photovoltaic system for powering the compact hydraulic power unit is made as an off-grid system, totally independent of an electricity network. The system stores electricity in a battery, the stored energy can be used at night or in combination with solar panels during the day. The diagram of the solar power supply system of the compact hydraulic group can be found in fig. 1. This contains the photovoltaic energy harvesting part with 2 photovoltaic panels, the battery for energy storage and the inverter for converting the DC voltage from the battery into single-phase AC voltage of 230 V for powering the electric motor. The 2 photovoltaic panels are connected by means of a DC fuse disconnector to MPPT charger, and the output from the charger is connected to a 12 V / 220 Ah lead battery. The inverter is supplied with DC voltage from the battery and the alternating current output is connected to a soft starter through a thermal-magnetic circuit breaker and a fuse switch disconnector. The electric motor is powered by a soft starter to have a smooth start and not to overload the inverter at start-up. The overload at start-up is explained by the fact

that upon initial energization of the electric motor, the rotor remains stationary, causing a current flow equal to the current in blocked state (inrush current). This current gradually decreases as the motor gains speed and generates a back electromotive force (EMF) in opposition to the power source. AC induction motors operate as a transformer with the secondary winding short-circuited until the rotor initiates motion, whereas brushed motors primarily exhibit winding resistance. Minimizing the load on the motor until it reaches a certain speed can shorten the duration of the initial transient phase. This is done by starting the hydraulic group with the flow switched to the tank (minimum hydraulic pressure) until the electric motor reaches the nominal speed.

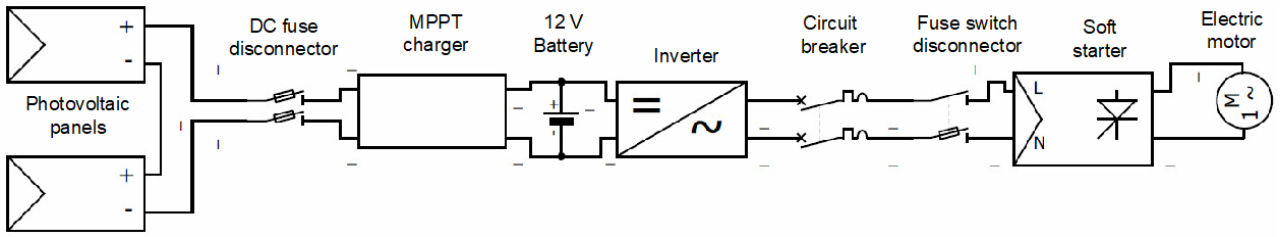


Fig. 1. The solar power supply system for hydraulic power unit

The electrical equipment of the photovoltaic system and the compact hydraulic group are placed in an enclosure protected against the penetration of water and dust. The electrical equipment consists of: electrical cabinet with electrical accessories, MPPT solar charger, 12 V battery and a shunt for monitoring the charging current and the current consumed. The electrical cabinet comprises: disconnectors, circuit breaker, soft starter, battery status monitor, a controller for adjusting the MPPT charger, signal lights and control buttons.
The solar charge controller has functions such as MPPT - fast Maximum Power Point Tracking, short circuit protection, reverse polarity, and high temperature.
The MPPT controller used is from the Victron Energy company and allows to find out information about the status of the solar charge controller and to set certain parameters. On the screen of this monitoring system, users can see information about the state of charge of the battery, the battery voltage, the load current and the amount of energy available from the photovoltaic panels. The device ensures uninterrupted and professional monitoring of information related to the photovoltaic system.
MPPT Controller Features and Functions can be seen in the Table 1.

Table 1: MPPT Controler Features

Feature / Function	Value
Displays the status of parameters in real time	panel power, battery voltage, charging current, output current.
The archive of information for the values recorded	last 30 days
Settings for the MPPT controller	battery voltage and type, max. current, bulk time, absorption voltage/time, float voltage, temp. compensation, et al.
Input voltage range	6.5 - 95VDC (battery) 5VDC (via VE.Direct cable)
Own consumption	< 4mA
Operating temperature range	-20 degrees C - +50 degrees C

Battery status monitor has the main function of calculating power consumption and battery charge status. The consumption in ampere-hours is calculated by integrating the electric current entering or leaving the battery. The equipment used is type BMV-702 from Victron Energy.
Monitored parameters of the battery:
- Battery voltage (V)
- Load level (%)

- Battery charge/discharge current (A)
- Ampere-hours consumed (Ah)
- The time until the discharge level is reached
- Visual and audible alarm: over and under voltage and/or low battery
- Programmable alarm relay.

The support on which the 2 solar panels are installed is placed next to the enclosure with the equipment (fig. 2).

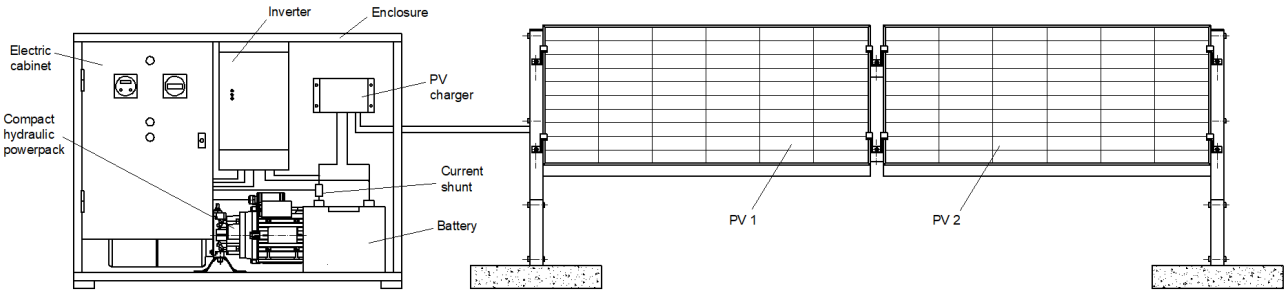
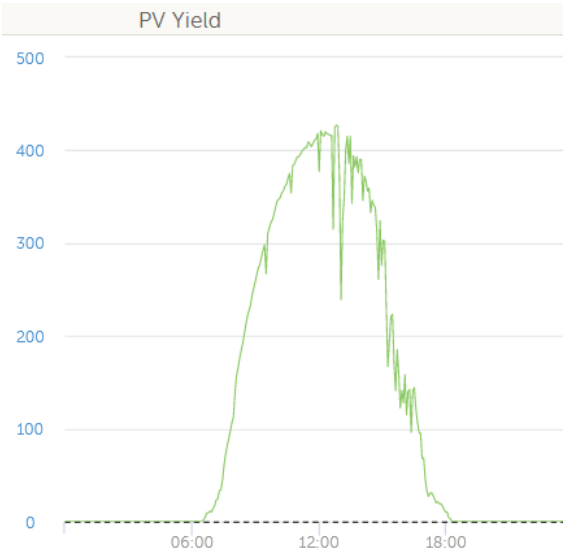


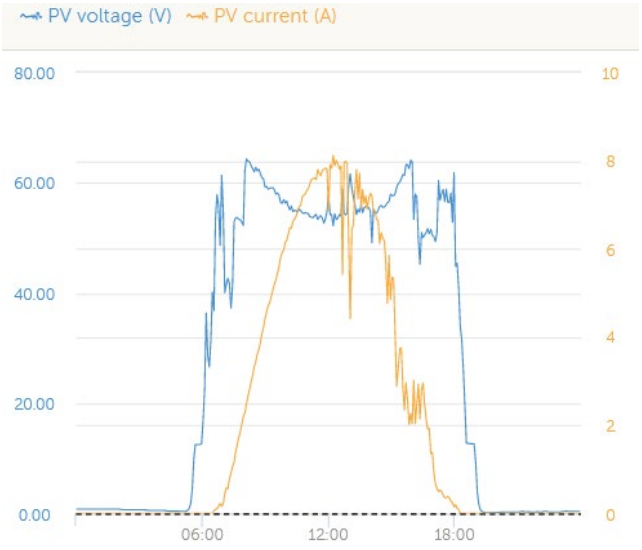
Fig. 2. Photovoltaic panels and enclosure with equipment

The technical characteristics of the photovoltaic system are:
- Number of photovoltaic panels: 2 pcs
- Installed power (peak power): 600 W
- Voltage at maximum power: 65 V
- Current drawn at maximum power: 9.38 A
- Overall dimensions of PV panels group: 2500 x 2000 x 800 mm.

Figure 3 shows the recordings during a battery charging with the group of 2 PV panels on a day in March.



a) PV Yield



b) PV voltage and current

Fig. 3. Recordings during battery charging

3. The compact hydraulic power unit

The pumping unit is the main component of a hydraulic drive system. In the present case, a 1500 W pumping group is used, which is mounted in the enclosure next to the electrical equipment. The hydraulic group [7] receives electrical energy from the photovoltaic system and transforms it into hydraulic energy, which it sends to the linear hydraulic motor, which transforms it into the mechanical energy required to actuate the mechanism of an equipment such as: irrigation canal

gate, valve, compaction press, etc. The hydraulic diagram of the pumping group (fig. 4) contains two directional valves with manual control, one for connecting / disconnecting the hydraulics and one for controlling the hydraulic motor connected to the system by means of 2 quick couplings.

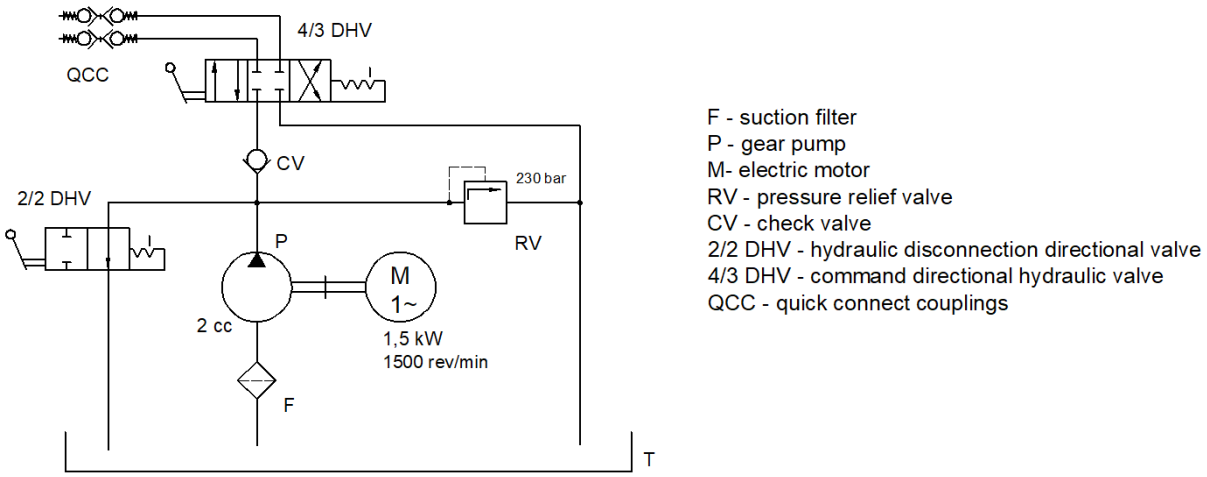


Fig. 4. Diagram of the hydraulic power unit

The hydraulic directional valves can be replaced with ones with electric control for a version of the system with remote control.
For remote control, the system must be completed with a controller through which the pumping group can be started and the hydraulic controls can be activated. Also, the system must be provided with a telemetry system that provides information about the SoC (state of charge) of the battery and the confirmation of the accomplishment of commands sent from a remote location [8]. To this end, a general purpose programmable logic controller, ESP32 microcontroller module [9], Arduino platform, etc. can be used.
Characteristics of the hydraulic group:

- Power of the pumping group: 1.5 kW
- Supply voltage: 230 Vac
- Maximum pressure: 250 bar
- Maximum flowrate: 3 l/min
- Manual operated 2/2 directional valve size 6 for disconnection of the hydraulics
- Manual operated 4/3 directional valve size 6 for hydraulic motor command.

In fig. 5, the hydraulic group can be seen during the testing and adjustment of the relief valve performed in the laboratory.

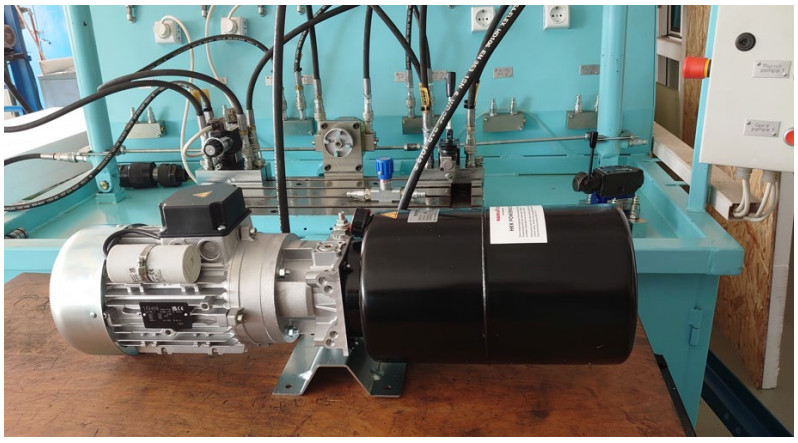


Fig. 5. Hydraulic power unit during laboratory testing

4. Conclusions

Examples of the use of solar photovoltaic energy, produced locally in areas that do not have access to the electrical grid are for: irrigation systems that use solar pumps, hydraulic actuation systems for irrigation canal gates, hydraulic drive for knife gate valve for the mining industry, etc.
The use of electrical energy obtained through the conversion of solar energy directly contributes to the reduction of noxious pollution, when it replaces energy that would otherwise come from burning fuels (e.g., in hybrid mobile machines); in isolated places, electricity from solar energy is the only solution to facilitate human activity.
Indirectly, local energy production contributes to reducing pollution; waste compactors of various sizes can be mentioned here. The local compaction of waste, which becomes possible even where there is no common electricity network, reduces the volume of waste, decreases the fuel consumption required for their transportation, and the application of "smart" solutions, such as the transmission of information about the state of the compaction equipment, contributes even more to reducing pollution.

Acknowledgement

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