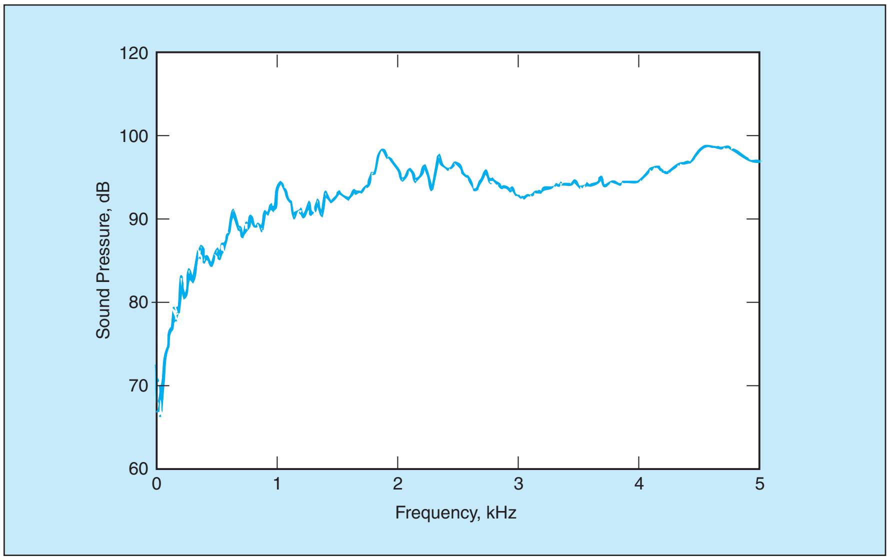

Figure 2. An **Audio Response** is shown for a piezoelectric-audio-device sound-pressure level measured at 1 cm without any sound enclosure using ±14 V.

surface of the piezoelectric actuator, a resonating chamber similar to a Helmholtz chamber is formed.

This work was done by Stanley E. Woodard, Robert L. Fox, and Robert G. Bryant of **Langley Research Center**. *For further information, write to R. P. Turcotte, NASA Langley Research Center: postal address 3 Langley Boulevard, Mail Stop 200, Hampton, VA 23681-2199; telephone (757) 864-8881; fax (757) 864-8314; e-mail address r.p.turcotte@larc.nasa.gov.*

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Photovoltaic Power Station With Ultracapacitors for Storage

Ultracapacitors offer advantages over batteries in this application.

John H. Glenn Research Center, Cleveland, Ohio

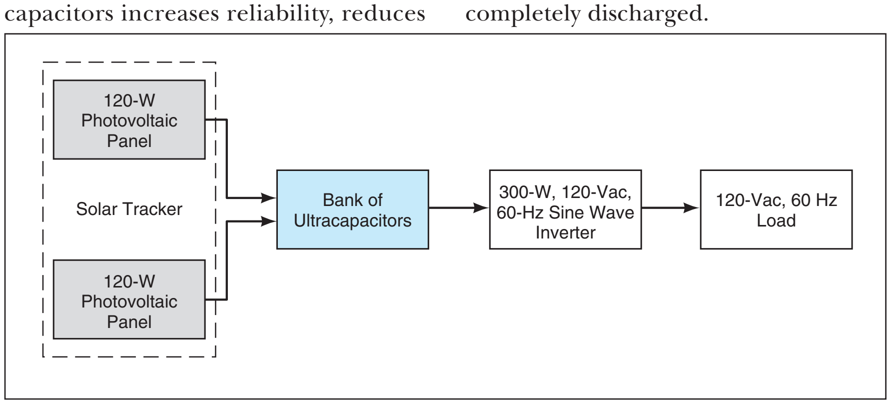
The figure depicts a solar photovoltaic power station in which ultracapacitors, rather than batteries, are used to store energy. Developments in the semiconductor industry have reduced the cost and increased the attainable efficiency of commercially available photovoltaic panels; as a result, photovoltaic generation of power for diverse applications has become practical. Photovoltaic generation can provide electric power in remote locations where electric power would otherwise not be available. Photovoltaic generation can also afford independence from utility systems. Applications include supplying power to scientific instruments and medical equipment in isolated geographical regions.

The reasons for choosing ultracapacitors instead of batteries in this power station are the following:

- Batteries are not particularly suitable for storing energy generated in photovoltaic power systems. Batteries must be kept adequately charged, and are not permitted to be completely discharged. The variability of available sunlight makes it difficult to satisfy this requirement.
- Batteries must be sized to accommodate peak load currents, which are usually much greater than average load currents.
- Batteries have rather short cycle lives and their internal chemical reactions cause deterioration over time.
- Batteries perform poorly at low temperatures.
- Ultracapacitors make it possible to overcome most of the aforementioned disadvantages of batteries.

The ultracapacitors in this power station are electrochemical units. Because these capacitors contain large-surface-area electrodes with very small interelectrode gaps, they have large volumetric capacitances. Capacitors can have cycle lives that are extremely long, relative to those of batteries; indeed, it may never become necessary to replace capacitors. The longevity of capacitors increases reliability, reduces life-of-system costs, and reduces adverse environmental effects. The longevity of capacitors is especially desirable for photovoltaic power systems, which are kept in service continuously for many years.

The power densities of capacitors exceed those of batteries. Therefore, high power can be drawn as needed and then capacitors can be recharged very quickly in preparation for the next high power demand. Capacitors have excellent low-temperature characteristics, continue to function without need for maintenance, and perform consistently over time. In addition, capacitors are conducive to safety in that it is easy to discharge them and they can be left completely discharged.



This **Photovoltaic Power Station** utilizes ultracapacitors (instead of batteries) as energy-storage devices.

The present power station includes two 5- by 2-ft (1.5- by 0.6-m) all-weather photovoltaic panels, each rated at a power of 120 W. The photovoltaic panels are connected in parallel to provide up to 240 W at a potential of 16.9 V. The photovoltaic panels are mounted on a solar tracker for tracking the path of the Sun to maintain efficiency (at up to 50 percent more than the attainable efficiency of panels mounted in a fixed orientation). The tracker is a thermally actuated device: it exploits solar heating and consequent differential thermal expansion to change the orientation of the panels.

The outputs of the photovoltaic panels are sent to the bank of ultracapacitors for energy storage. Capacitors are excellent for this application in that a complex voltage regulator is not needed, as it would be if batteries were used. The ultracapacitors can tolerate voltage variations up to their maximum voltage rating. The ultracapacitors feed a 300-W, 60-Hz sine-wave inverter for powering various ac loads. A sine-wave inverter was chosen to minimize the generation of noise and to supply clean power to the load.

Additional photovoltaic panels and ultracapacitors can easily be added to satisfy an increased power demand. The photovoltaic panels and ultracapacitors in this power station have a minimum expected life of 25 years.

This work was done by Dennis J. Eichenberg, John S. Kolacz, Richard F. Soltis, and Paul F. Tavernelli of **Glenn Research Center**.

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17177.