Reports

Electrical System for Home Conversion and Storage of Solar Energy

Abstract. Energy storage has long been a problem in connection with home utilization of solar energy. A solution which utilizes solar semiconductor cells for conversion to d-c power is proposed. The d-c power is used to drive an alternator which is connected directly across the residential power lines. Thus a-c power is delivered to the power lines when a surplus of power is available in the home and is used in other parts of the power distribution system. At latitude 42°N there is 3 times more yearly energy recoverable than is used by an average residence on the basis of a 10-by-10-m collection area. At the present state of technical development the cost of such a large-area semiconductor solar cell would be prohibitive.

The approximate 1 kw/m^2 of solar power available at sea level on a clear bright day with the sun at its zenith has attracted considerable attention in terms of methods of utility, and many techniques have been proposed for making use of this energy (*1*). Commercial utilization in metropolitan and urban areas does not appear to be economically attractive because of the cost of the land. Home utilization could be carried out by using roof areas. The major problem here is one of storing energy during periods of peak solar power for use during the night and when the sun is not shining. Systems have been suggested and tried in which energy is stored in specific heat and heat of fusion of water and other suitable chemicals. With these systems a large storage volume is required, together with recirculation of the fluid.

A new energy storage system which has attractive prospects is shown in Fig. 1. In this system, semiconductor cells (*2*) are used to convert the solar power into direct-current electricity. This electrical power is used to drive a d-c motor, which in turn is mechanically coupled to an alternator. The output of the alternator is connected directly across the power lines and is thus always operating at approximately synchronous speed. A rectifier located between the semiconductor cells and the d-c motor prevents any power from flowing back into the solar cells. An auxiliary semiconductor cell is used to monitor the solar power and control the field excitation of the d-c motor at the correct value. With this method of excitation the d-c motor and associated system always represents the optimum load to the main semiconductor cells so as to abstract maximum power therefrom at all levels of solar activity. During periods of significant solar irradiation, the alternator is driven slightly above synchronous speed and feeds power into the power lines to be used locally or, if the local demand is not sufficient, to be delivered to the power lines for distribution. During the time that energy is fed into the power lines, the conventional kilowatt-hour meter is reversed in operation and kilowatt-hours are subtracted. Thus, basically, the storage method used in this system is the power distribution system which generally extends over wide areas of the United States. The distribution system averages out the power demands over the large area encompassed by the interconnected power companies. A similar system for returning power to the utility company was tried some time ago in connection with recovering energy from the wind (*3*). The individual power-generating plants of the interconnected power companies represent potential energy storage points. Under some circumstances a central energy-storage facility such as a reversible hydroelectric system might be required.

Calculations have been made to determine the annual consumption and recovery of energy for a typical resident. Fritz and MacDonald (*4*) have tabulated isolines of average daily solar radiation received on a horizontal surface at the ground for the different months of the year. This tabulated information can be used to compute a yearly energy flux of 1347 kw hr/m^2 for Detroit, Mich. If Daniels' suggested (*5*) roof area of 100 m^2 is used and if a semiconductor cell conversion efficiency of 10 percent and a rotary converter conversion efficiency of 75 percent are assumed, the yearly energy available electrically as 60-cy/sec power is 10,100 kw hr. The average yearly consumption of electrical power per residence for 1958, obtained by extrapolating published data (*6*), is 3400 kw hr. Thus, it appears that even at the latitude of Detroit (42°N) the total yearly solar energy available is nearly three times the average yearly energy requirement. More southern latitudes of the United States would be roughly 50 percent more favorable but, on the other hand, a more typical residential yearly energy consumption would also be roughly 50 percent greater and is

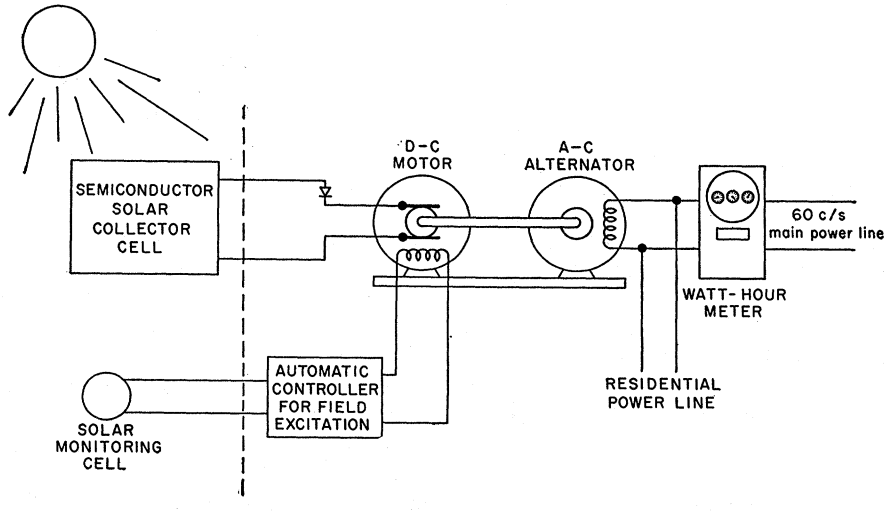

Fig. 1. Solar energy utilization system.

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Type manuscripts double-spaced and submit one ribbon copy and one carbon copy.

Limit the report proper to the equivalent of 1200 words. This space includes that occupied by illustrative material as well as by the references and notes.

Limit illustrative material to *one* 2-column figure (that is, a figure whose width equals two columns of text) or to *one* 2-column table or to *two* 1-column illustrations, which may consist of two figures or two tables or one of each.

For further details see "Suggestions to Contributors" [*Science* **125**, 16 (1957)].

currently increasing at 7 percent per year.

If the generated electricity is valued at the current residential rate of 2 ct/kw hr, the solar energy would represent a potential total yearly return of $200. For the system described the peak power capability of the rotary equipment would have to be 11 kw. The costs of the rotary equipment, assuming that an inexpensive induction motor design is used for the alternator, would probably be less than $1000. At the present state of technical development the cost of a large-area semiconductor converter would be prohibited. For instance, the fabrication of a 100 m^2 panel from currently available solar cells would cost in the neighborhood of $250,000. It is worth remembering, however, that this cost is predominately one of fabrication and will be greatly reduced when new techniques—for instance, evaporative methods of fabrication—are developed.

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References

1. F. Daniels and J. A. Duffie, *Solar Energy Research* (Univ. of Wisconsin Press, Madison, 1955); *Proc. World Symposium App. Solar Energy, Phoenix, Ariz.*, 1955 (Stanford Research Inst., Menlo Park, Calif., 1956); *Trans. Conf. on Use of Solar Energy, The Scientific Basis* (Univ. of Arizona Press, Tucson, 1958).
2. M. B. Prince, *J. Appl. Phys.* **26**, 534 (1955); J. J. Loferski, *ibid.* **27**, 777 (1956).
3. P. C. Putman, *Power from the Wind* (Van Nostrand, New York, 1958).
4. S. Fritz and T. H. MacDonald, *Heating and Ventilating* **46**, 61 (1949).
→ F. Daniels, *Sci. Monthly* **82**, 247 (1956).
6. T. R. Gates, Ed., "Residential consumption of electric power 1925-57," *Economic Almanac-1958, Natl. Ind. Conf. Board* (Crowell, New York, 1958).

6 August 1959

Pavlov the Empiricist

I am grateful to Conway Zirkle for his letter [*Science* **128**, 1476 (1958)] calling attention to a 1958 translation of a 1957 article by A. L. Takhtadzhan in *Botanichesky Zhurnal* in which an "article" (Zirkle's designation, Takhtadzhan does not call it so) in a 1927 issue of *Pravda* by I. P. Pavlov on the inheritance of acquired characters is cited. I missed the Takhtadzhan article (the *Botanichesky Zhurnal* is not my usual pabulum), and while I heard of the Pavlov item in *Pravda*, I could not locate the particular issue at the time of writing my article [*Science* **128**, 758 (1958)]. I have now seen the issue (13 May) and would like to report on it and on some related information and interpretation.

Pavlov did not "publish" an "article" in *Pravda*, not even a letter. What happened was that M. Levin reviewed in *Pravda* a 28-page popular pamphlet by E. Smirnov, "The Problem of the Inheritance of Acquired Characters," published by the Communist Academy, and took Smirnov to task for patent bias in favor of the inheritance of acquired characters and for including the Pavlov experiments as alleged positive evidence for it (that was in 1927). Levin stated: "The problem of Pavlov's mice has been taken off the docket by Pavlov himself. Comrade Gutten addressing Academician Pavlov on the significance of his experiments [on inheritance], recently received from him an unambiguous answer. Here is what the conscientious scientist, used to heeding seriously the requisites of the methodology of the natural sciences, writes:

1 March 1927

'Most esteemed Mr. Gutten:
The first experiments with the hereditary transmission of conditioned reflexes in white mice have not yet been confirmed with improved methods and stricter control, so that I should not be classed among those authors who affirm such transmission.

With true respect,
IV. PAVLOV.' "

Again, I should like to note that my article did not say that nothing was published in Russian about the inheritance experiment before 1949. What it said was that Pavlov's report of it, published in 1923 in four places in English, did not appear in Russian before 1949. The experiment itself was communicated to the 1923 Russian physiological conference by Studentsov, who actually performed it and published it as an abstract in Russian in the *Fiziotogichesky Zhurnal S.S.S.R.* [**7**, 312 (1924)]. The data in the Studentsov abstract differ slightly from those in Pavlov's report: Studentsov reports 298, 114, 29, 11, and 6 conditioning trials for the five successive generations versus Pavlov's rounded figures of 300, 100, 30, 10, and 5.

Zirkle, like B. Gruenberg whom he quotes and like a number of other American scientists, tends to attribute Pavlov's initial acceptance of the inheritance data to "an over-zealous assistant" (presumably Studentsov, who, incidentally, appears to have ended—and begun—his scientific career with the experiment, there being no published mention of him since then). It seems, however, reasonable to assume that Pavlov would not have been so gullible if he had not shared the Lamarckian predisposition, common to Russian bioscientists—and to the intelligentsia in general—even before the Revolution, and if he had reviewed critically the general evidence on the topic; moreover, it might be added that the experiment was performed with mice and not with dogs, and with a "free-running" and not a "harness" technique—both new to the Pavlov laboratory. And these factors, plus Pavlov's sense of his historical destiny as an innovator and tester of nature, were probably the basis of his failure to repudiate formally the inheritance doctrine even after he obtained no evidence in support of it. "Have not yet been confirmed" and "the question . . . must be left open" are the expressions used by him in the aforementioned letter and in the footnote to the 1927 English translation of his *Conditioned Reflexes* (*1*).

Obviously, however, Pavlov's remaining open-mindedness about the inheritance of acquired characters relates little to his status as a thoroughgoing empirical scientist. What does relate is his attitude towards controlling influences of attendant nonempirical sociopolitical and philosophical views. And here Pavlov's record is surely unblemished and strikingly unique and exemplary. He stated in his 1906 Huxley lecture: "Natural science is the work of the human mind directed to nature and investigating nature without borrowing any kind of concept or interpretation from sources other than nature itself" (*2*), and there is not an iota of evidence that in the remaining 30 years of his life he ever in even one instance swerved from the objective. Indeed, just as he resisted any Marxist incursion into his experimental system (*3*), he became in the last years of his life expressly suspicious of what he believed to be distortions of science by religion and other prevailing philosophies. He quotes scornfully Sherrington's saying to him, in 1912: "No, your experiments [on conditioning] will not go over in England because they are materialistic" (*4*), and a later published statement, "*if* nerve activity have relation to mind" (*5*) (italics mine). "Sherrington," Pavlov declared, "is a dualist definitively dividing his being into two halves: a sinful body and an eternal, immortal soul" and assuming that "the brain is a piano, a passive instrument, from which the soul, the musician, can extract any melodies it likes" (*6*)—and he proceeds to label similarly a number of other Western scientists as dualists and animists. Whatever the merits of the labels (*7*), there is no doubt that Pavlov was in all respects an unstinting and uncompromising empiricist and objectivist in a pioneer area in which others often succumb and stray. Perhaps, indeed, he was the 20th century's empiricist par excellence.

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