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STATUS OF STORAGE BATTERIES DEVELOPMENT AND AREAS OF THEIR APPLICATION

P B MATHUR

Central Electrochemical Research Institute, Karaikudi 623 006

ABSTRACT

Energy crisis of 1970s created new demands and opened vast areas of application of electrochemical power sources particularly those of the storage batteries. Different fields of applications of storage batteries have been analysed in this paper with respect to their techno-economic requirement of the energy. There are about a dozen basic parameters in which one battery system differs from another. All these parameters are neither possessed by a single battery system nor required simultaneously in any particular application. In this paper, an analysis of the technical requirements of each area of application is made and the batteries matching these characteristics are identified. This exercise is conducted to help the selection of most suitable battery systems for research and development.

INTRODUCTION

The energy crisis in the 1970s gave a great impetus to the exploration and development of a host of battery systems for different areas of applications. Many countries [1-5] launched electri vehicle, utility load levelling and solar energy storage programmes in mid seventies. The Department of Energy (DOE) USA implemented by means of five mission-oriented projects covering different stages of development of prospective batteries to the end stage of their commercialisation. The batteries fabricated by the contractors are independently tested at the National Battery Test Laboratory (NBTL) of Argone National Laboratory. The batteries included lead-acid, nickel-iron and nickel-zinc types. The USA is reported to have spent about $ 97 million in 1980 alone for battery research and development.

Some of the other areas of applications of storage batteries such as utility load levelling and solar storage were so projected along with electric vehicle (EV) application, encompassing the development of several other advanced secondary batteries, viz. Na-S, Zn-Cl_2, Zn-Br_2, Redox, as well as metal air cells (Zn-Fe). In Japan, the candidate batteries selected under this programme are-Na-S, Zn-Cl_2, Zn-Br_2, Redox and Pb-PbO_2. Japan is reported to be spending $ 430 million during 1980 to 1990 for the battery projects.

R&D work on storage battery made significant progress in several other countries also like Australia, Germany, U.K., Sweden and Italy. Some of the advanced storage batteries are listed in Table I.

Table I : Advanced storage battery systems for large scale storage of energy

A. Acidic battery :
- i) Lead acid
- ii) Zn-Cl_2
- iii) Zn-Br_2
- iv) Redox battery Cr/Fe

B. Alkaline battery :
- v) Ni-Zn
- iv) Ni-Fe
- vii) Fe-Air
- viii) Zn-Air

C. Molten salt and non-aqueous batteries :
- ix) Na-S
- x) Li/Al-TiS_2

2. STORAGE BATTERIES, CHARACTERISTICS AND AREAS OF THEIR APPLICATIONS

Although a host of storage batteries have been developed an many of them have already been commercialised during the las three decades, all of them cannot be considered as suitable for a areas of requirements of secondary batteries. The selection of battery for an application is a critical one to be based on th simultaneous evaluation of the nature of the application and th characteristic parameters possessed by each battery system. Som of these features of a battery are : i) cell voltage, ii) energ density, iii) power density, iv) service life, v) life cycle, vi) self discharge, vii) charging and discharge rates, viii) energy efficiency ix) freedom from maintenance, x) operation temperature, xi) cos and xii) import component. The applications listed in Table I differ from one another in their technical requirements. Hence the battery to be considered suitable for these applications shoul possess matching characteristics.

Table II : Storage battery applications	Energy requirements of storage units (KWh)
i Load levelling and peak sharing	1,00,000
ii Solar energy storage	20-25
iii Wind energy storage	20-25
iv Electric vehicle	10-300
v Satellite application	10-100
vi Transport applications:	
a) SLI battery for Railways	3-12
b) Traction battery	2-24
c) Automobile batteries	1-5
vii Defence applications:	
a) Airforce starter batteries	2-10
b) Naval submarine battery	1080
c) Army:	
i) Automobile battery	1-5
ii) Communication battery	0.1-5
viii Domestic appliances :	
Emergency light etc.	2-5

2.1 Load levelling and peak sharing : Since the domestic and industrial consumption of electricity supplied by centralised power stations in urban and rural areas is not uniform during the night and day cycle periods, and since the power loads cannot be altered from time to time as per fluctuations in consumption, there is a need for energy sharing and load levelling during off peak periods for economic production of energy and avoiding the damage to the power plants [6-8] This requirement calls for energy storage devices of as high a capacity as hundreds of megawatt hours to be installed by the side of power plants. The battery should possess large life cycles, high power density, high energy efficiency, low self-discharge and low cost. Projected battery goals are indicated in Table III.

Table III : Battery goals for electric utility load levelling applications

Battery capacity	:	5 MWh
Life cycle	:	3000
Cost per cycle	:	0.5 C/KWh
Operating and maintenance cost	:	0.5 mil/KWh

Low cost REDOX, Na-S, and Zn-Cl_2 batteries are the three storage systems most suitable for this application.

2.2 Solar and wind energy storage : Solar energy can be converted into electricity by means of photovoltaic cells made out of polycrystalline or amorphous silicon or other materials or by photovoltaic electrochemical cell. It is reported that the world production of silicon solar cells has reached 22 MW of which 18.6 MW were based on crystalline and polycrystalline silicon. The production is estimated to grow to 500 MW/year by 1990 for ribbon silicone and 200 MW/year for other varieties. The growth of solar energy generation in India is bound to increase tremendously because of large sun-shine in the country. Efforts are being made in India by the Department of Non-Conventional Energy Sources to develop this particularly for rural sector. Unlike thermal or hydel power stations, solar energy generation can be decentralised by setting up mini unattended power stations of 20 KWh to 40 KWh. These units are provided with panels of solar cells connected to a storage battery which is charged during the sun-shine and discharged in dark hours. The system is connected to lamps, pumps and other domestic appliances in rural sector [9-11(a)].

A battery to be used for storing solar energy should have (a) high charging efficiency, (b) low self discharge, (c) high power density, (d) long service life, (e) high discharge efficiency over a wide range of temperatures, (f) freedom from maintenance and (g) low cost. Ni-Zn and Pb-acid batteries are the most suitable battery for this application.

Proposed target specifications of photovoltaic battery are (a) 6 volts, 100 Ah; (b) 6 Hr nominal discharge rate; (c) 80% depth of discharge daily duty cycle; (d) 2000 cycles to an 80% depth of discharge; (e) recharge in less than 8 hrs; (f) 80% round trip energy efficiency, (g) self-discharge rate of less than 1% per week; (h) totally maintenance-free operation.

The requirements of wind energy storage are identical to those of solar energy storage and so the same systems of battery proposed in latter case would suit the former.

2.3 Electric vehicle (EV) battery : An EV gets all its motive power from an electrochemical power source and hence battery is the heart of an EV. The operational requirements of different types of EVs have been well laid down [1-5, 9, 10, 12-14]. The requirements of a representative 4-passenger urban vehicles are given below :

a) Range on one single charge — 240-320 km; b) Running speed — 80 km/hr; c) Crushing speed — 69 km/hr; d) Top speed — 120 km/hr; e) Battery life — 1,60,000 km; f) Battery energy requirement — 0.14-0.16 Kwh/tonne vehicle wt/km; g) Specific energy — 56 Wh/kg; h) Specific power — 104 Wh/kg; and i) Cyclic life (80% DOD at C/3) — 800.

a) High energy density, b) high power density, c) large life cycles and d) low cost are the major requirements of an EV battery. Many of the high energy battery systems do not possess high power density and vice versa. Since low cost is the major requirement of this mass consumer item, a hybrid battery system consisting of a pair of batteries one to provide high power for cranking the motor of EV and a second high energy density battery to provide large energy at lower rate of discharge for running EV to long distances in a single charge, has been considered as a viable alternative to a single battery system possessing all the three major requirements. Ni-Zn battery coupled with a metal-air (Fe-Zn) is the most prospective hybrid battery system, where Ni-Zn is the high power medium-cost battery and metal-air battery is a low-cost high energy density system. As single battery system Ni-Zn or Zn-Cl_2 is the most prospective candidate batteries for this area of application. For most of the present day battery needs of road transport vehicles, for starting, lighting and ignition and of railway carriers for traction, lead-lead acid battery is quite suitable on cost analysis and it does not need any substitution for the present and in near future.

2.4 Satellite application : A satellite needs a storage battery to store solar energy [15-16]. Basic requirements of a satellite battery are a) high energy density, b) high power density, c) high charging rate capability, d) long service life of 5 to 10 years, and e) high reliability. Cost is not a consideration here since reliability of the battery is the most critical requirement. Li-Al/TiS_2 non-aqueous battery system is the most prospective candidate for the satellite application. The development goals laid down for this application are shown in Table IV :

Table IV : Battery requirements of satellite applications

Specifications	Low earth orbit	Geosynchronise orbit
Total energy (KWh)	5-29	12-60
Specific energy (Wh/kg)	66	100
Operating voltage (V)	28-150	28-150
Base line power (KW)	10-50	10-50
Peak power (KW)	100	100
Calender life (Yr)	5	10
Cycle life	29200	1000
Charge time (Hr)	0.916	22.8
Discharge time (Hr)	0.583	1.2
Time frame	1990-2000	1990-2000

2.5 Defence applications

a) *Aircraft starter battery* : High energy density and power density batteries are needed as starter batteries for defence aircrafts at the time of emergency landing. The battery should be capable of operating over a wide range of temperatures. Ag-Zn and Ni-Cd are the two high density battery systems most suitable for this area of application.

b) *Naval-submarine application* : Submarine battery is a very high capacity energy system (1000 KWh) used to provide power to operate the vehicle. The battery should be a) low cost and b) high energy density system. Na-S, is a better competitor to the lead-acid battery presently used for this application.

c) *Army applications* : Army needs smaller units of storage battery, but in large numbers for man-pack and mule-pack telecommunication equipments. Basic electrical requirements of such a battery are a) high energy density, b) high power density, c) large cycle life, d) good low temperature performance and e) low cost. Li-Al/TiS_2/FeS non-aqueous system is most suitable for this application. Other suitable batteries for this application are Ni-Zn and Ni-Cd.

2.6 Domestic applications : A very low cost high energy density battery is much needed for consumer market for emergency lights and for operating many domestic implements in urban and rural sectors. No suitable battery is available today for this area of application. Even lead-acid battery is too expensive for the purpose. Iron-air battery is an answer to the problem as it is constituted of very cheap iron and air electrodes.

CONCLUSION

From the present survey, it may be noted that the demand of the storage batteries is very large for eight areas of applications listed in Table II. Although more than a dozen batteries have reached the advanced state of development in different countries, each battery possesses a combination of a few characteristics different from one another. On the considerations of the nature of requirements of storage batteries and also on the consideration of battery parameters, an effort has to be made to match the batteries against the applications. This exercise has helped the identification of batteries listed in Tables V and VI which are most suitable for the existing and futuristic requirements of the storage batteries for wide areas of applications [17, 18]. National efforts are therefore needed to develop and commercialise these batteries indigenously for meeting present and future needs of the country. Although USA and Japan are investing millions of dollars per annum on their development, India can at least spend a fraction of this amount on them so that it may not have to solely depend on the import of products and technologies in this vital energy area in years to come and also for strengthening our own technology base.

Table V : Storage batteries and identified aras of their application.

Areas of application	Suitable battery systems
i Load levelling/peak sharing	a) Redox battery b) Na-S c) $Zn\text{-}Cl_2$
ii Solar energy storage	a) Ni-Zn b) Lead acid
iii Wind energy storage	a) Ni-Zn b) Lead acid
iv Eelctric vehicle	a) Metal-air and Ni-Zn hybrid battery b) Ni-Zn battery
v Satellite battery	a) $Li\text{-}Al\text{-}TiS_2$ nonaqueous
vi Transport application	a) Lead acid b) Ni-Fe
vii Defence applications :	
a) Defence aircraft	i) Zn-Ag and ii) Ni-Cd
b) Naval submarine	Na-S,
c) Army communication	$Li/Al\text{-}TiS_2$ non-aqueous
viii Domestic applications	a) Fe-Air

Table VI : Storage battery necessitated R&D efforts

Battery systems	Areas of application
i Lead acid	1. Solar and wind energy storage 2. Transport
ii Ni-Zn	1. Solar and wind energy storage 2. Electric vehicle 3. Defence communication equipments
iii Fe-Ni	1. Transport (Railways traction)
iv Zn/Fe-Air	1. Electric vehicle 2. Domestic appliances
v Redox	1. Load levelling
vi Na-S	1. Load levelling 2. Submarine
vii $Li/Al\text{-}TiS_2$	1. Satellite

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