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Multiyear Load Growth Based Techno-Financial Li-ion Discharge and Corrosion Behaviors in a Microgrid Located in Algeria

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Abstract— The primary current-collector materials used in lithium-ion cells, aluminum and copper, are both susceptible to environmental degradation. Localized corrosion occurred on bare aluminum electrodes during simulated ambient-temperature cycling in an excess of electrolyte. The highly oxidizing potential associated with the positive electrode charge condition was the most important factor.

In contrast to typical aqueous electrolyte pitting, each site was filled with a mixed metal/metal-oxide product, forming surface mounds or nodules.

The status quo for relaying such confidence is economic and technical planning models, which are used to design microgrids and distributed energy resources DER. Long-term DER investments and short-term DER dispatch are typically determined by these models. This paper investigates the optimal cost analysis of a hybrid (photovoltaic-diesel) renewable energy system (HRES) in the Adrar region based on the Total Net Present Cost (TNPC). The Hybrid Optimization Model for Electric Renewable is used to perform the optimal cost analysis of HRES. Furthermore, the system is simulated for each time step for each year of the project's 20-year lifespan. The trade-off for this model, which captures battery storage levels from year to year, photovoltaic performance degradation, and diesel cost escalation above the inflation rate, is that the model is more precise, but the calculation takes longer. To begin, we ran the model without Multi-Year and used the Optimizer to find the best system design. The optimal system for the single-year model includes a Danvest generator with 760 kW, 200 kWh of recommended Li-ion storage, and a slightly lower COE of $0.309/kWh. Various scenarios have been simulated, taking into account variations in the power production of the gasified biomass generator, and various solutions to ensure the balance generation/consumption have been analyzed.

Index Terms—Corrosion, Diesel, Financial planning optimization, Hybrid energy system (HES), Li-ion battery, Multi-year planning, Microgrid, Photovoltaic, Technical planning optimization, Total net present cost.

I. PROBLEM STATEMENT

The research effort focuses on how the battery, which is used to secure energy supply in the pv diesel hybrid system, degrades then affect both technical and financial system performances. For many applications, lithium batteries are essential power storage technologies. Their great power and energy density are primarily responsible for their success [1]. As a result, several researchers are working to create batteries that are more potent, affordable, long-lasting, and secure [2].

Due to their endurance, lithium batteries have a limited capacity for power and energy over time.

Operating circumstances have an impact on the deterioration rate. The most important and well researched aging variables are really battery temperature, state of charge (SOC), voltage, depth of discharge (DOD), and current magnitude [1]-[3].

Lithium plating, active material loss, and solid electrolyte interphase (SEI) development are among the primary aging processes [4]. Batteries can degrade while in storage for a number of different chemical reasons, including the limited thermal stability of materials (such as silver oxide in silver-zinc batteries) or the corrosion of metal electrodes (such as lead in lead-acid batteries or lithium in lithium-thionyl chloride batteries).

Increased battery deterioration rates can be attributed to improper charging voltage management, for example, overcharging lead-acid batteries can lead to overheating and excessive electrolyte loss through gassing [4]–[5].

We take into consideration rate-dependent losses, capacity-dependent temperature changes, and calendar-life-dependent temperature changes. The Rainflow Counting approach is used by the model to estimate cycle lifespan. We take into account a battery with a constant internal temperature. Otherwise, the interior temperature of the battery bank is determined using a lumped thermal model.

The literature is divided into four focal lenses based on a content analysis of 232 academic articles: technological, institutional, viability, and user-centric. The debate around RE is dominated, according to our findings [6].

The MESSAGE (Model for Energy Supply Strategy Alternatives and their Overall Environmental Impacts) is the topic of our paper work [7].

Figure 1 shows a block schematic of the lifespan model for lithium-ion batteries.

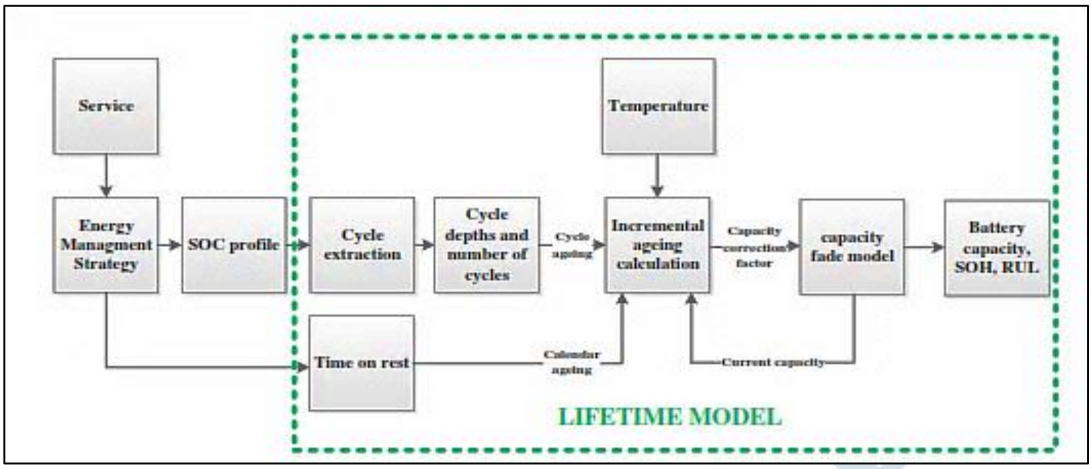


Fig.1 A block schematic of the lifespan model for lithium-ion batteries

II. METHODOLOGY

This paper work focus on the analysis of the de degradation of electric performances of hybrid (wind Diesel-Battery) renewable energy system (HRES) for a Saharan region in Algeria, as it happens Ouargla (31°56°.952N 5°19.5012E) under the effect of corrosion battery degradation.

Primary lithium batteries have previously been found to have potentially major corrosion issues.

So, the goal is accomplished dealing simultaneously with the optimal cost analysis based upon the Total Net Present Cost (TNPC).

Hence, an energy system consisting wind turbine, diesel generator and battery is designed to satisfy a certain electrical load.

We have modeled a power system's behavior and economics which includes installation and operational cost. We focused on the Modified Kinetic Model adds a series resistance, temperature effects on capacity, temperature effects on degradation rate, and cycle-by-cycle degradation based on depth of discharge (DOD) [6].

The process of MATLAB integration with HOMER is used for all the calculation.

A. System under study

The system under study is presented in figure 2.

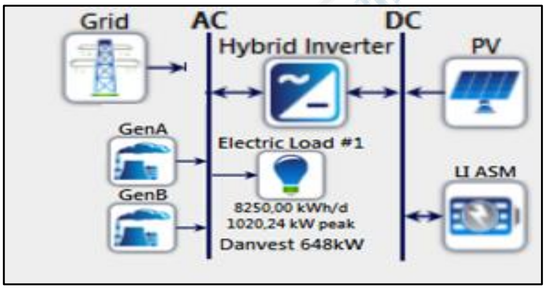


Fig. 2 Single line diagram for wind- diesel- Battery hybrid system

B. Objectives

In order to reduce the payback time (PBP) of BESS and enhance the revenue from selling electrical energy for PV on-grid systems with BESS, the major goal of this article is to explore its viability. A PV system's levelized cost of energy may be calculated by taking into account the two things listed below:

1) Various battery technology options.
2) Varying battery storage system sizes (by calculating the size of the BESS as a proportion of the daily PV production total).

The motivation for conducting a focused study was provided by the two electrolyte and extended service-life capability of the lithium-ion technology pro- formulations that were used nominally as representations of those originally; the ultimate objective was to ascertain whether reliability and service life would be jeopardized by chemical degradation of the building materials.

C. Input parameters

* No energy will be purchased from the grid, yet, as we require to investigate the cumulative cost of energy from the PV system using the batteries.

* It is expected that generation would at least cover the linked load. The load was set up to be a minimum load so that: being able to perform the simulation without making a simulation mistake.

* The algorithm takes batteries into account. but demands the replacement cost at the most recent values the battery's end-of-life (EOL) date. Making a calculation replacement price and anticipated expenditures for each BESS Technology that is displayed earlier in Table II is used and interpolated to determine the cost on an annual basis, and they are used and interpolated to get the year-by-year cost.

* Over the course of the project, yearly inflation is taken into account at 5.71%. For all renewable energy technologies, a discount factor of 10.70% has been used,

during 20 years system lifetime which represent battery lifetime.

III. MAIN RESULTS

After calculation, feasible combinations of RES and Optimal size of various components in different microgrid scenarios based on the HOMER Simulations are presented on the results bellow.

A. Economic evaluation

The goal of the economic aim is to reduce the overall expenses while minimizing the impact on the network.

Owners or operators of distributed generations DGs may take this option into consideration.

The key constraints from an economic perspective are the DGs' physical constraints, which may influence the economic dispatch. Since these resources are close to the load site, the reduction of transmission lines has an influence on Virtual Power Plant VPP's ability to reduce losses costs.

In actuality, the removal of transmission lines can minimize losses since electricity is generated close to local demands. The network operator in this instance stands to gain from the problem [8].

The cost of various power production methods is evaluated using several energy economics models. Particularly for renewable energy, where the cost of capital varies greatly among nations and technologies, the models need the use of well-calibrated assumptions for the cost of capital or discount rates.

There are several benefits to VPP, including fewer outages, faster network recovery, integration of DGs, reduced line congestion, lower peak demand, etc. This virtual distribution firm fosters attitudes toward shifting distribution companies' paradigms [9].

Numerous scholars have since expanded on the idea of VPP. There have been several definitions of VPPs recently, but they all have the same basic idea: a VPP is a collection of traditional DGs and renewable (RES) resources that may be operated as a single power plant to provide a load more effectively [10]–[11]. The cost of these products will either be avoided entirely or will be very cheap thanks to VPP, which might also lower the cost of failure and the quantity of air pollution emissions.

VPP has a lot of benefits, including fewer outages, faster network recovery, integration of DGs, less line congestion, lower peak demand, etc.

The NPV technique evaluates all cash flows during the investment year against one another (i.e., year 0). The NPV is calculated on the premise of a specific interest rate and takes into account the fact that future investment revenues will be less valuable than in year 0 of the investment. The simulations' main objective was to ascertain the Li-ion BESS's investment's net present value (NPV), which was used to supply the forecast error balancing service [10].

Figures 3 and 4 show respectively the net cost by component and the nominal cash flow by component.

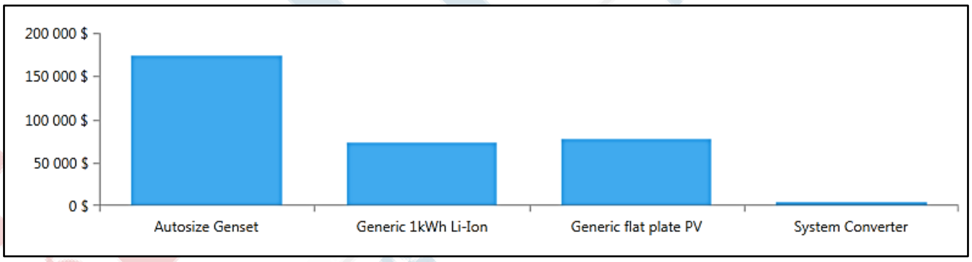


Fig. 3 Net present cost by component

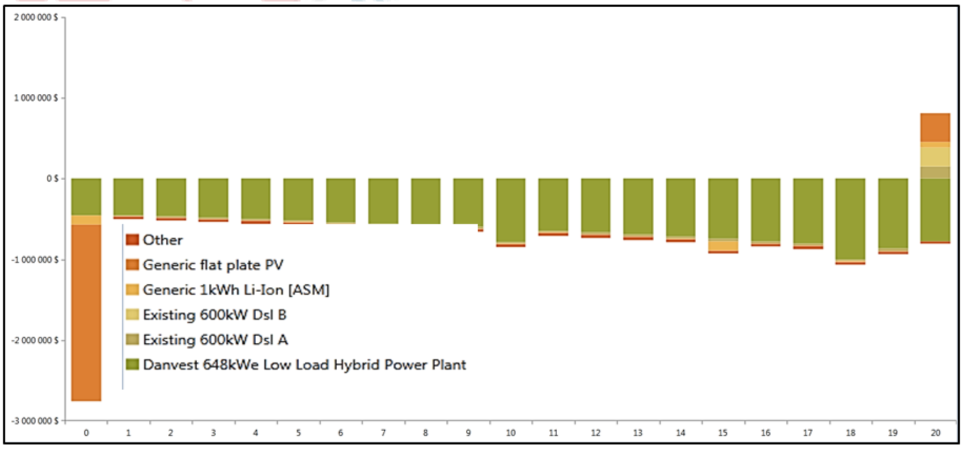


Fig. 4 Nominal cash flow by component

Li-ion battery cells are still costly today. As a result, the objective of this research case is to determine the Li-ion battery price at which purchasing Li-ion BESS for the purpose of delivering Forecast Error Balancing will be financially beneficial.

The forecast error balancing service's 20-year total income as a function of the Li-ion BESS SOC allowed interval id presented on figure 5.

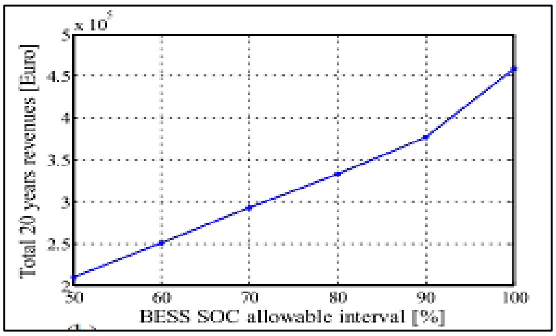


Fig. 5 Battery SOC vs total lifetime revenue

B. Technical evaluation

The performance of the network has increased technically. Without taking into account resource costs or profits, the goal of network performance is to reduce power losses, improve voltage fluctuations, and reduce network congestion. System operators mostly take this choice into consideration [11].

The percentage of energy that came from renewable sources and was sent to the load is the renewable fraction which is illustrated on figure 6.

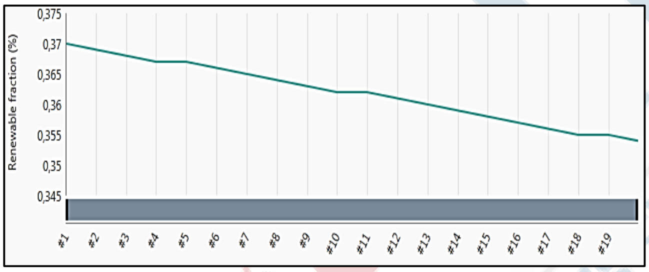


Fig. 6 Renewable fraction evolution over lifetime

We see the annual decline caused by PV performance deterioration throughout the course of the system's lifespan.

On the figure 7 bellow, battery energy in and out are superposed and their evolution over lifetime illustrated.

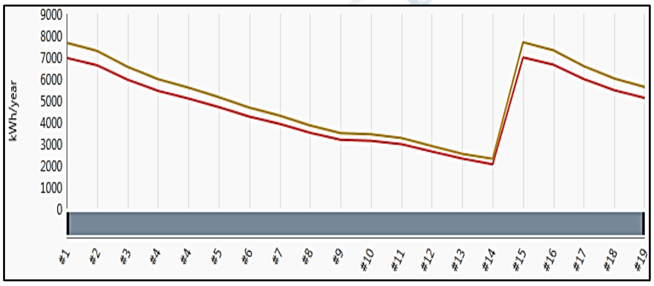


Fig. 7 Battery energy evolution over 20 operating years

Bellow on figure 8, is illustrated the battery degradation cycling.

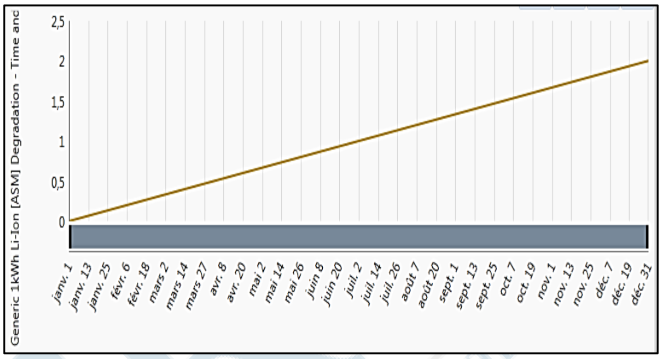


Fig. 8 Hourly Li-ion degradation cycling

The hourly degradation due to temperature of the Li-ion battery performances over time is presented on figure 9 bellow.

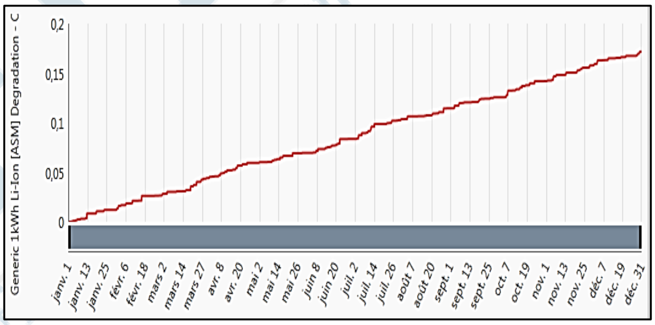
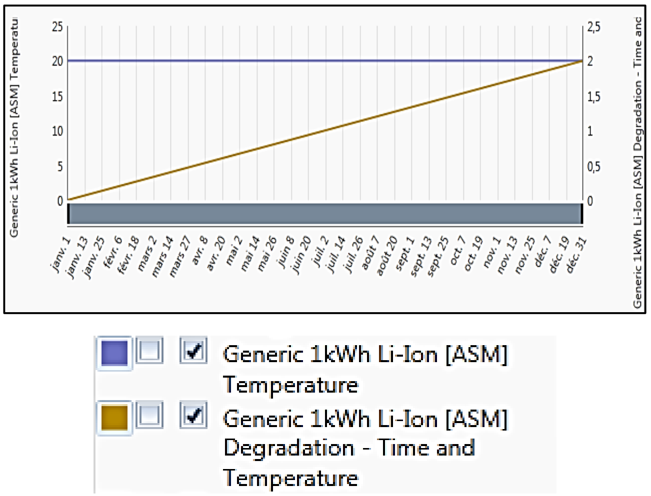
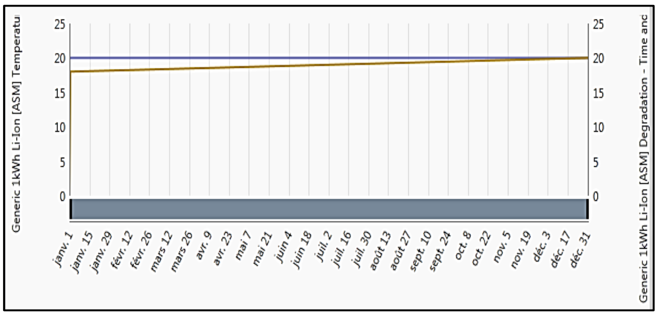


Fig. 9 Hourly Li-ion degradation- Time and temperature

The same degradation during two periods of operation are shown on figure 10.



(a) 1st year



(b) 10 years later

Fig. 10 Hourly degradation due to temperature of the Li-ion

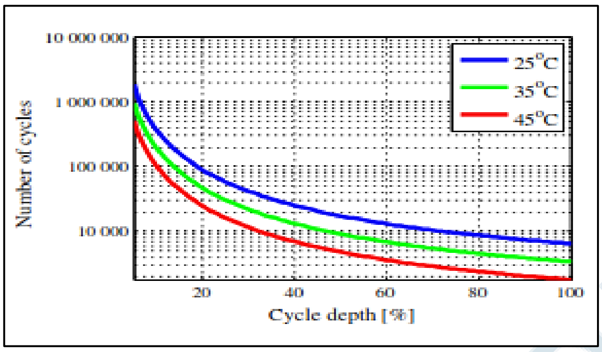


Fig. 12 Li-ion degradation- Cycling

We can readily see that the evolutions have become worse with time.

The operating temperature does have a significant impact on the battery life, in fact.

The lifespan will be halved at 30 °C. The service life will be further diminished by 50% at 40 °C. As a result, our lifespan will be one-fourth as long as it would be at 20 °C. According to the norm, the longevity drops by 50% for every 10 degrees Celsius above 20 degrees.

Figure 11 illustrates the calendar degradation rate vs SOC and Temperature which represent the aging factors, based on an aging model we present later.

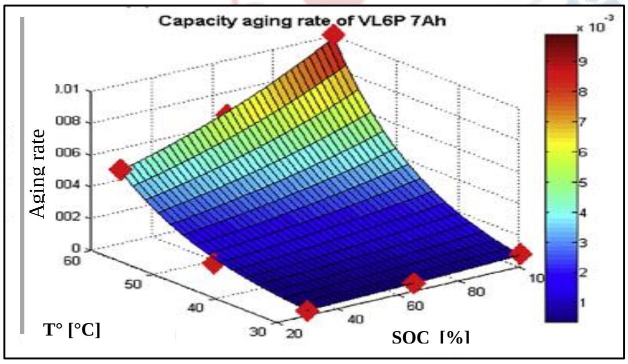


Fig. 11 Battery capacity degradation aging rate

With rising temperature, state of charge, and current strength, the rate of aging rises exponentially. However, two distinct aging patterns were seen in proximity to both high and low temperatures.

In fact, at high temperatures, calendar aging outpaced total aging without being influenced by the amount of the current. On the other hand, at low temperatures, power cycling significantly accelerated overall aging, and the response rate was obviously dependent on the current density.

The second factor that affects the electromotive force is temperature. On the figure 12 is illustrated the temperature effect on the battery's number of cycles.

Low temperatures can affect battery capacity, while high temperatures can damage batteries and diminish their useful lives. We identify the rates of deterioration during power cycling. For the sake of space, just the capacity findings will be covered in this section. The capacity fading logarithms change linearly over time. The regression coefficients are really quite near to one, demonstrating the consistency between the two aging modes and the time-dependent features found in calendar aging and power cycling.

Nevertheless, cycling at around SOC $^{1}/_{4}$ 60% with a switching SOC between 40 and 80% or 50 to 70%, as described in the battery performances over time.

Different calendar aging is the result of the experimental section than at a 60% SOC that remains constant. SOC really varies, and for greater precision, this must be taken into account. Temperature in the cell is contemplates self-heating because to the aging temperature. Thus, the calendar degradation rate is averaged without taking temperature into account. Interestingly, over the temperature ranges of -5 °C-25 °C and above, the aging rate significantly rises with both lowering and increasing temperature 25 °C -60 °C, correspondingly.

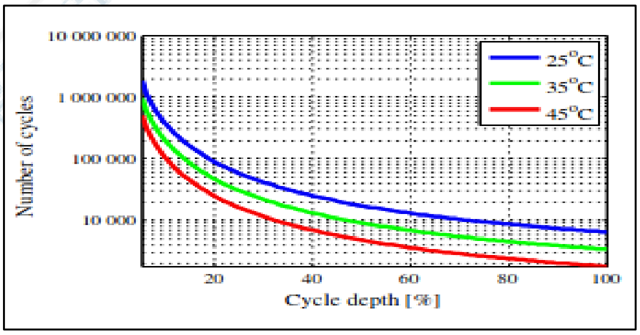


Fig. 12 Li-ion degradation- Cycling

IV. CONCLUSION

Using levelized cost of energy (LCOE), technico-economic optimization of a PV/Li-ion BESS hybrid system was carried out, during its whole lifetime. When using solar radiation to recharge batteries, the need for battery replacements is taken into account.

The size of the BESS is significantly influenced by the battery replacement number, which is directly influenced by the depth of discharge. When combined with a diesel generator and BESS, employing more RES results in a more consistent electrical supply. Low time resolution may make the use of BESS with PV impractical. It was shown that simulation accuracy increased with increasing time resolution (1 minute). The system would assume that PV production and power consumption were closely matched, which is incorrect, and the tiny charge/discharge cycles would not be taken into account if time resolution were low (60 minutes).

In summary, 20% daily PV production rate is a good starting point for BESS implementations using renewable energy, supported by a Power Purchase Agreements PPA of at least ($0.140 /kWh) for most technologies I can do it. Finally, the optimization of simulations and results can be adjusted for future changes in cell parameters and other variables used to optimize the process like discount rate or required PV system size. The pricing strategy is a crucial component of the power market. Different techniques may be used in pricing strategy. Price for market penetration or pricing to increase market share, economic price or no low-frill price and using psychological pricing methods.

Modern rechargeable lithium-ion batteries are appealing because it is possible to handle the corresponding deterioration processes in reel-world settings.

The potential for long-term chemical deterioration of the cell hardware components to negatively impact electrical performance, capacity, life, and/or safety is a worry for these latter applications. These consequences can be brought on by two ways, the experimental corrosion behavior; and a rise in lost. To prevent the creation and expansion of passive corrosion layers, understanding the failure mechanism can be substantially aided by modeling this inherent process. Aluminum's tendency to corrode can result in the development of corrosion products that can damage or passivate the materials used in active electrodes, or a breach in the hermeticity of the cell that can lead to electrolyte loss or the entry of pollutants (which can also react with active materials).

To prevent the creation and expansion of passive corrosion layers, understanding the failure mechanism can be substantially aided by modeling this inherent process. Aluminum's tendency to corrode can result in the development of corrosion products that can damage or passivate the materials used in active electrodes, or a breach in the hermeticity of the cell that can lead to electrolyte loss or the entry of pollutants (which can also react with active materials). We notice that the electrochemical system fracture frequently has a corrosive tendency. In Li-ion batteries, the Li reactions leads the host material to become more brittle and generally produces a drop in the anode's fracture toughness when Li enters and a reduction in the cathode's fracture hardness when Li extracts. The chemomechanical stress, the kinetics of Li transport, and the Li embrittlement effect all affect the dynamics of crack formation. This fracture is a result of recurrent deformation and contributes to a key aging mechanism.

In the other side, the pricing strategy is a crucial component of the power market. Different techniques may be used in pricing strategy. Price for market penetration or pricing to increase market share, economic price or no low-frill price and using psychological pricing methods.

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