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DATA DRIVEN ANALYSIS OF ENERGY MANAGEMENT IN ELECTRIC VEHICLES

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Abstract: *Inevitably, there has been a concerted policy push at the national level to promote electric vehicles. In electric vehicles, the progress stands and falls with the performance of the battery. Lithium-ion batteries are considered in this research project, as they are the most crucial component in the electric vehicle power system and require accurate monitoring and control. Proper battery optimization in electric vehicles requires a meticulous energy management system. The energy management system is bound for estimating the battery state of charge, state of health, various distinct factors in the system, and subsystems in real-time. The state of charge estimation accounts for the prevention of over-charge and over-discharge of batteries and provides cell balancing. Traditional SOC estimation approaches, such as open-circuit voltage (OCV) measurement and current integration (coulomb counting), are relatively accurate in some cases. However, estimating the SOC for Li-ion chemistries requires a modified approach. This project presents the Kalman filtering algorithm for the state of charge estimation that provides precise results for a fair computational effort.*

Keywords- *Electric vehicles, Energy management systems (EMS), Hybrid EV, Lithium-Ion Batteries, State of Charge (SOC)*

I. INTRODUCTION

The era of electrical vehicles started with Hybrid electrical Vehicles within the last decade and gained huge attention from analysis societies and automobile manufactures. This crossbreeding of the vehicle powertrain makes the engine smaller and a lot more economical. The HEVs' potentials in potency augmentation, energy-saving, and emission reductions have resulted in several sure-fire industrial products. Later, Plug-in Hybrid electrical Vehicles introduced the automobile market as a bridge from HEVs to full-electric transportation. They use larger batteries than ancient HEVs that may be absolutely charged before beginning. because of burning Engines in HEV/PHEVs, they're not entirely inexperienced. On the opposite hand, Battery electrical Vehicles use on-board power storage and electrical motors for energy generation.

BEVs are absolutely inexperienced as a result of they use batteries because of the solely energy supply of the vehicle, and also, they're terribly economical because of the utilization of electrical motors rather than ICEs [1]. In distinction with ICEVs and HEVs, BEVs have a brief operational vary, and also, their pricey battery includes a restricted service life, that limits BEVs' wide market presence at the tip. the event of Associate in Nursing economical Energy Management System (EMS) for BEVs is crucial to handle the problems mentioned higher than. For safe and reliable operation of batteries on electrical vehicles, the net observance and state of charge estimation of the batteries are essential. Associates in the Energy Management System are able to do this; therefore, overall vehicle performance powerfully depends on this EMS [2]. The golf range of Associate in nursing eV was solely 40–100 miles, 3–4 times but ICE vehicles. Adding to the matter is that the current lack of battery charging infrastructure. Therefore, to stop EVs from running out of charge on the road and going passengers stranded, the flexibility to predict their residual vary is required. The primary step in residual vary prediction is to grasp what quantity capability remains within the battery, additionally called its state of charge (SOC). Standard methodology for SOC estimation is the voltage-based methodology, that infers SOC by Associate in Nursing electrical circuit voltage (OCV)-SOC look-up [4]. However, an OCV measure needs an extended amount of rest before the terminal voltage converges to the particular OCV. Recently, a shot targeted on developing model-based filtering ways [5-7] geared toward the state of charge estimation. UKF is Associate in Nursing improved version of the Kalman filter that applies Associate in Nursing unscented remodel, a technique for shrewd the statistics of a variant propagating through a scheme. In UKF, the state distribution is portrayed by letter points, capturing the mean and variance of the state distribution. The simplified implementation of the UKF algorithmic program offers a computationally economical possibility for runtime SOC analysis on-board vehicles.

II. State of Charge

State of Charge is one in all the essential parameters for batteries, however its definition presents many various problems. In general, the SOC of a battery is outlined because of the quantitative relation of its current capability to the nominal capability (Qn). The manufacturer's nominal capability and represents the utmost quantity of charge which will be kept within the battery. The SOC are often outlined as follows: [9]

SOC(t) = Q(t)/Qn ----- (1)

The state of charge of batteries in an exceedingly battery management system is just like the fuel meter in an exceedingly standard fuel automobile. The first operation of the SOC is to speak the self-generated battery state to the motive force and, at identical time, avoid issues like overcharge and over-discharge. At present, most electrical vehicles outline SOC from the attitude of electrical charge amount, thus during this equation, Qc is that the residual power of the battery at the instant of calculation, and its unit is Ah; letter is that the total capability of the battery, and its unit is Ah. Qe is the battery charge [11]. In fact, the battery sometimes varies with several factors, and this equation has to be changed. The equation below is a lot of normally used.

$$SOC(t) = SOCt_0 - \int_{t_0}^{t} \frac{\eta I}{C_n} d$$ ----- (2)

In this equation, SOC(t) is that the nominal capability of the battery, and its unit is Ah. Therefore, the worth is sometimes but 100%. The present lithium-ion batteries have a coulomb potency of ninety nine.9% or a lot of [11].

III. State of Charge Estimation

Category	Method
Direct Measurement	Open circuit voltage method
	Terminal voltage method
	Impedance method
	Impedance spectroscopy method
Book-keeping Estimation	Coulomb counting method
	Modified Coulomb counting method
Adaptive systems	Neural network
	Support vector machine
	Fuzzy neural network
	Kalman filter
Hybrid methods	Coulomb counting and EMF combination
	Coulomb counting and Kalman filter combination
	Per-unit system and EKF combination

Figure 1. Methods of SOC Estimation

Regarding State of Charge estimation strategies, 3 approaches are chiefly being used: a coulomb count technique, voltage technique, and Kalman filter technique [8]. These strategies will be applied for all battery systems, particularly HEV, EV, and BEV. This project focuses on the Kalman Filter technique that is mentioned.

IV. KALMAN FILTER

The Kalman filter is an algorithmic rule to estimate any dynamic system's inner states—it can even be wont to estimate the SOC of a battery. Compared to alternative estimation schemes, the KF mechanically provides dynamic error bounds on its own state estimates. This technique for SOC estimation treats the battery as an influence system. By modeling the battery system to incorporate the sought after unknown quantities (such as SOC) in its state description, the KF estimates their values and provides error bounds on the estimates.

It then becomes a model-based state estimation technique that employs a mistake correction mechanism to supply time period predictions of the SOC. It will be extended to extend the potential of time period so estimation victimization the extended Kalman filter. The extended Kalman filter is providentially applied once the battery system is nonlinear, and a linearization step is required. Although Kalman filtering is a web and dynamic technique, it wants an appropriate model for the battery and precise identification of its parameters.

The general mathematical type of the battery model is as follows.

Equation of state: $x_{k+1} = f(x_k, u_k) + w_k$ ----- (3)

Equation of observation: $y_{k+1} = g(x_k, u_k) + v_k$ ----- (4)

In Equations 3 & 4, u_k is the input of the system, typically pertaining to the variables like current, temperature, residual electrical amount, and internal resistance. y_{k+1} is that the output of the system, typically pertaining to the voltage, x_k is that the state amount of the system, together with the calculable price of SOC. Functions $f(x_k, u_k)$ and $g(x_k, u_k)$ check with the nonlinear equations established on the battery model, however they have to be linearized within the calculation method.

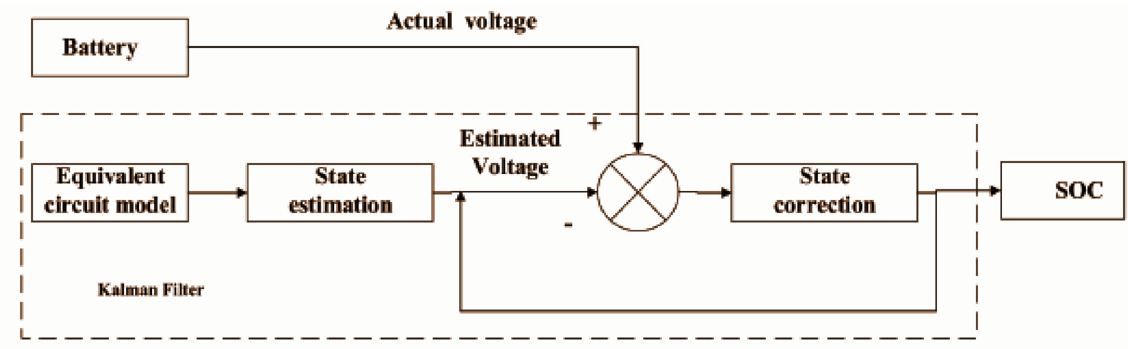

Figure. 2 Principle of Kalman Filter

The principle of this technique is shown in Figure 3. It describes the battery as a system composed of AN equation of state and observation equation, considers SOC as an enclosed state of the system, establishes a state-space model, and makes the minimum variance estimation for SOC. Its disadvantage is that the accuracy mostly depends on establishing the battery equivalent model, and therefore the error chiefly comes from 3 aspects: the time variability of the model, the non-linearity of the model, and therefore the approximate treatment of noise. In sensible applications, it's employed in varied batteries, particularly in hybrid-electric vehicles with violent current fluctuations. At present, several improved strategies are generated to support this technique [9]. as an example, the Extended Kalman Filtering (EKF) technique linearizes the nonlinear system; the Unscented Kalman Filtering (UKF) technique is obtained by adding U to KF, that deals with the nonlinear drawback with a likelihood distribution.

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V. EXTENDED & UNSCENTED KALMAN FILTERING

If the system is non-linear, then we will use a linearization method at every occasion step to approximate the nonlinear system with a linear time-varying system. The state-space model is linearized at every occasion instance, that compares the expected worth with its measured battery terminal voltage to correct the estimation parameters for SOC. However, if the system is extremely non-linear, linearization error could occur thanks to the shortage of accuracy within the first-order Taylor series underneath an extremely nonlinear condition thanks to the benefits of EKF, several researchers have applied this methodology to the study of battery SOC. Compared to alternative extended Kalman filter algorithms, the sturdy pursuit cubature extended Kalman filter is associate degree correct SOC prediction and quicker process time.

The advanced EKF methodology encompasses a higher performance than generality EKF, KF, and therefore the quantity unit investigation methodology in terms of effectiveness and dynamic ability [12]. In contrast to its linear counterpart, the EKF, in general, isn't an associate degree best calculator (it is perfect if the measuring and therefore the state transition model area unit each linear, as in this case, the EKF is similar to the regular one). Also, if the state's initial estimate is wrong, or if the method is sculptural incorrectly, the filter could quickly diverge, as a result of its linearization. The EKF's acquainted structure is preserved, however stability is achieved by choosing a reliable positive resolution to a fake algebraic Riccati equation for the gain style. otherwise of up EKF performance is to use the H-infinity results from strong management. The extra term is parametrized by a scalar, that the designer could tweak to realize a trade-off between mean-square-error and peak error performance criteria.

A nonlinear Kalman filter that shows promise as associate degree improvement over the EKF is that the unscented Kalman filter (UKF). In the UKF, the likelihood density is approximated by a settled sampling of points representing the underlying distribution as a mathematician.The EKF methodology is nice at the primary and second-order of a non-linear model however is unhealthy at an extremely nonlinear state-space model. The Unscented Kalman filtering (UKF) algorithmic program is employed to handle this downside. UKF is an associate degree updated version of EKF that applies a discrete-time filtering algorithmic program and unscented rework to resolve filtering issues. UKF supported unscented transformation was planned to avoid Taylor series enlargement weakness compared to EKF [15].

VI. WHAT WE PROPOSE

Comprehensive EMSs are units presently found in transportable physical science, like laptop computer computers and cellular phones, however they have not been absolutely deployed in EVs and HEVs. This is often as a result of the quantity of cells during a vehicle's battery is many times larger than that in transportable physical science. Moreover, a vehicle's battery is intended to be a durable energy system and a high grid. In alternative words, batteries for EVs and HEVs have to give high voltage and high current. These build EMSs for EVs far more difficult than those for transportable physical science. Current, voltage, and temperature ought to be measured to boost state pursuit capability in real-life applications. Data acquisition and storage area unit important components of the EMS computer code to investigate and build info for system modeling. Charge management could be a scheme governing the charge-discharge protocol. Most subsystems in EMS area unit complete modules, and hence, information transfer throughout the EMS is needed.

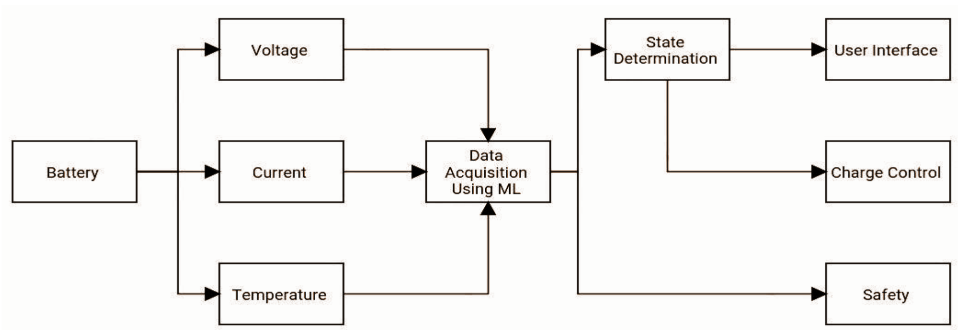

Figure. 3 Proposed Energy Management System

Determination of SOC is going to be integrated into a capability assessment that additionally presents the battery's life standing and sets the in operation limits consistent with progressive algorithms, like symbolic logic, neural networks, state-space-based models. The target of cell equalisation is to maximise battery performance while not overcharging or over-discharging. Its nature is to create the SOC levels of cells nearer to every alternative. Thus, the correct SOC estimation of every cell is crucial for rising equalisation.Intelligent information analysis is needed so as to produce battery fault warning and indicate out-of-tolerance conditions. The interface ought to show the essential data of the EMS to the users. The remaining change ought to be indicated on the dashboard consistent with the SOC of the battery. in addition, abnormal baleful and replacement suggestions area unit required to tell the users in terms of estimating and predicting the battery.

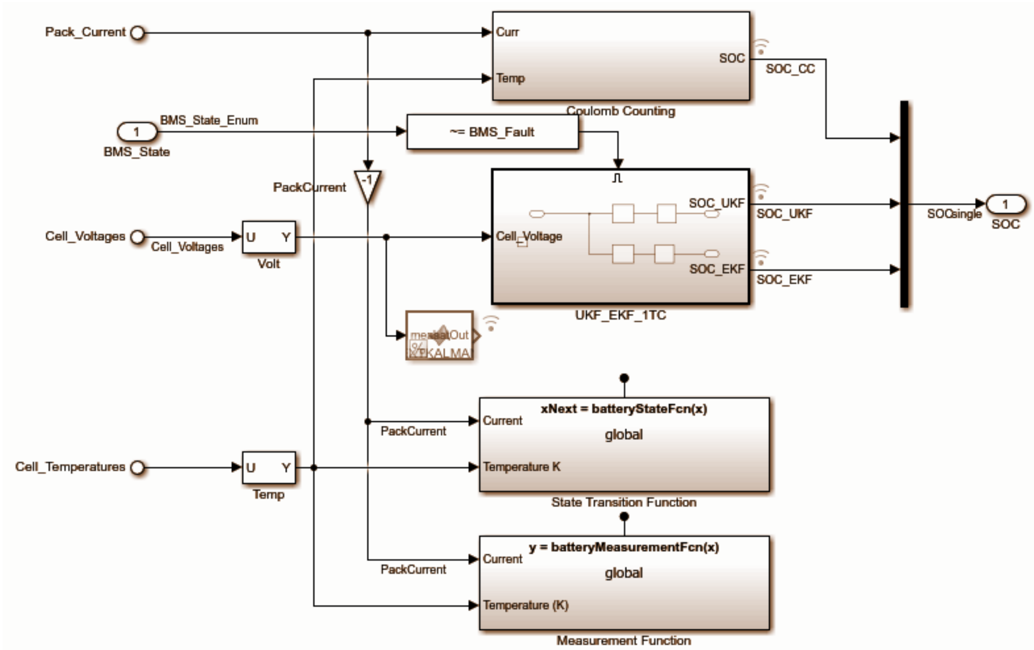

Figure. 4 Simulink Design of SOC Estimation

VII. BATTERY MODELLING

Many equivalent circuit models are projected to represent the chemical science method of battery victimization electrical components to model battery system dynamics. Establishing a battery model is tough because of the sophisticated chemical science mechanisms of batteries. Currently, battery modeling for SOC determination is usually developed from numerous equivalent circuit (RC network) models, distinct for various material characteristics and accuracy requirements[16]. These model parameters were predominantly achieved in terms of the physical characteristics of the precise anode and cathode. However, external factors, like environmental temperature and discharge current load, can create these stationary models inaccurate during a dynamic surroundings. As a result, model choice is often targeted on EMS.

VIII. CONCLUSION

As batteries at the core energy sources in EVs and HEVs, their performance dramatically impacts EVs' salability. Therefore, makers are seeking breakthroughs in each battery technology and EMSs. Chemical reactions within the battery are subject to operative conditions, and hence, the degradation of battery might vary in numerous environments. Developing a comprehensive and mature EMS is crucial for makers United Nations agency would love to extend their products' market share. The first considerations of EMSs were mentioned during this paper. Associate EMS framework was projected to take care of the deficiencies of current EMSs in each analysis and industrial product. Supported previous work, specific challenges facing EMSs and their attainable solutions were given as a solid foundation for future analysis. Because of variable things in real-world applications, a typical resolution wasn't wished. Supported the precise scenario, totally different methods ought to be applied to boost and optimize the performance of EMSs in future EVs and HEVs. State of Charge (SOC) is that the battery's actual capability is expressed as a proportion of the fully-charged capability. SOC estimation may be a vital performance of battery management systems (BMSs).

An adaptational SOC estimation technique that mixes Coulomb reckoning and battery voltage model victimization the unscented Kalman filter (UKF) to unravel these issues. The dynamic SOC model was developed to support the Coulomb reckoning principle. UKF, that is close-looped, was then accustomed to infer the SOC from the present and voltage measurements. As a result, the developed technique doesn't need previous info of the initial SOC and is powerful to activity noise. This feature is substantive for energy unit applications as a result of once the SOC of energy unit changes because of self-discharge or variable environmental conditions, this technique self-corrects the SOC. SOC estimation provides info for the BMS to stay the battery operating at intervals a secure operative window. With an associate correct SOC computer in situ, the battery pack is accustomed to its limit and doesn't ought to be over-engineered, leading to reduced price.

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