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Parameter Identification of Super Capacitor using Recursive Least Square Technique

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Abstract: Super capacitor is an electrical invention which store electrical energy in the form of charge and discharge it very fast, unlike the batteries. Any device require almost ideal parameters for proper functioning. This paper emphasises on the parameter detection of SC two arm design using recursive least square technique which adaptively reduces the error. In this paper, we assumes the parameter values to obtain input values of our technique then by using signal processing system, results are obtained. Results are also compared with the actual parameter values graphically. Ideal devices have minimum losses and so the maximum efficiency is obtained.

Keywords: Equivalent circuit modeling, Recursive least square technique, Signal processing, Super capacitor, Two branch design .

I. INTRODUCTION

Since the planet turns out to be increasingly cognizant about issues of environmental change and ozone harming substance emanations, there is a solid move achieving wagons with electric drive frameworks. These Electric Vehicles (EV) have the benefit of no gas emanations when contrasted with the conventional vehicles with interior ignition motors. To meet the application of EV's, energy storage system came into picture.There are many energy storage systems like battery, flywheel, pumped hydro, capacitor, super capacitor, thermal fluid storage. Amongst them the most popular and flexible energy pool device is the super capacitor electricity accumulator system.

A Ultra capacitor is an electrochromic invention comprising of two poros anodes detached by a layer known as saparator and inundated in an electrolyte that reserve charge electro statically. The separator just allows the particle portability however forestalls electric contact. . Electrolyte is additional significant segment that influences SC execution. The widespread necessities for the electrolyte incorporate huge potential scope, large ionic fixation, huge electrochemical security, poor resilience, minimum thickness, minimum unpredictability, and economic. SCs stock electrical energy chiefly utilizing the arrangement of the twofold laminate capacitor design at the contact between the anodes and the electrolyte.

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This electricity stockpiling system includes no synthetic stage or creation change. SC's have different focal points interestingly with batteries, like high density of power generally in the scope of 5-15 kW.kg-1 [1], or the potential to course power by charging what's progressively, discharging power at a more snappy rate than batteries. This limit provides critical guidance for their application to EVs, where they need to be regularly charged / discharged with difficulty in doing something annoying with long-lasting unchanged batteries (PB, N-Cd, MNiH Li-atoms). Contrasted with traditional capacitors, the high capacitance of SCs starts from the huge explicit region of the electrodes, which is to a great extent controlled by the existing cathode substances and their physical properties.

Currently industrial SC have a minimum rated voltage (2.3 V) with capacitance in the range of 1500 F. Greater voltages possible by a relevant series/parallel assembly of that sort of single units [2].The utilization of this system in realistic uses anticipates a final design, that anyway contrasts from the pattern utilised for electrolytic capacitors, considering its innovation presents a nonlinear conduct. In reality simulating DLC's is as yet an unfamiliar land and currently three distinct methodologies are popular.

Primary class of models is Electrochemical model which relying on the electro chemical laws[3]. At first it is most likely as the conventional electrolytic capacitor. Later these are modified as electrical double layer (EDL) capacitor into pair of characteristically unambiguous surfaces, i.e., the Stern surface (Helmholtz layer) and the diffuse surface (Gouy-Chapman layer). This model outline the interior paragons precisely; despite that, they are relatively strong but imperfect for realistic use in power electronics and online monitor. Latter class of procedures are contingent on equivalent circuits[4]. This model utilize parameterized RC (capacitor-resistor) systems to mirror the electrical conduct of SCs. They have clarity and simplicity of execution because of utilization of ordinary differential conditions (ODEs) in design details. This model is plainly clarified in next section. Third set of technique is founded on utilization of system designation techniques and in specific soft computerized theories as artificial neural networks to design the nonlinear performance of SC[3]. An approach of positive feedback artificial neural network organization about a pair of hidden layer and with back propagation training was stated to produce a dynamic sample of SC. Nevertheless this predict the performance using datasheet and doesn't calculate the parameters.

II. REPRESENTATION AND ANALYSIS OF SC

A.Representation

Equivalent circuit representation of SC is most popular and we start with the multiple arm representation.

The multi-branch equivalent circuit design of Ultra Capacitor is demonstrated. It appears that each branch comprise the equivalent capacitance and resistance in series. For the multi-branch circuit model of the SC, every branch can portrait various practices of the SC at different moments. The identical multiple branch system design has an advantage of the higher precision. But the multi branch model is tricky to analyse, we go for the three-branch model.

The definitive equivalent three-branch system pattern is pictured in Fig.1. This pattern can illustrate the instant, short-term and long-term behaviour of the SC.

For the greater consideration of load potential alterations of the SC, Faranda [6] choose a series mutable capacitance Ci and an comparable resilience Ri as the early arm of the three-branch illustration, as presented in Fig. 2 .Conforming to the design, the transient proportion between the load potential and the mutable capacitance of the SC possibly as noted in practical. On the other hand, the parameter detection would become more complex because of the variations of Ci in the course of the charge and discharge actions [4].

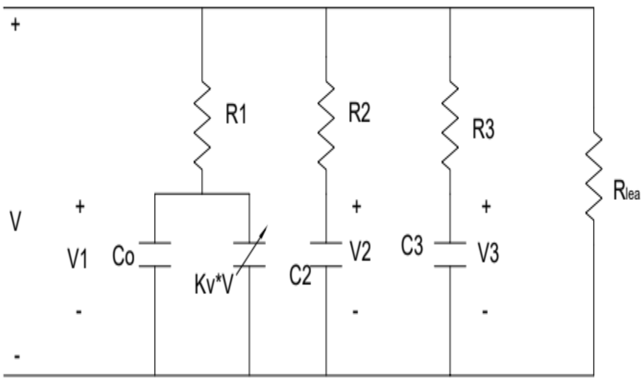

Fig.1 Three branch model of SC

Appertaining to the three-arm framework, various enhanced equivalent circuit designs of SC were suggested [4][6]. With the aim of reflecting the self-discharge phenomena of the SC, scholars put forward the two-branch design with leakage resistance in 3rd arm [2][6], as outlined in Fig. 2.This paper emphasizes on the 2-branch model outlined in Fig.2 for its clarity and easy analysis like [2][4][5].

This model describes the all-time behaviour of SC which could be appropriate for practical engineering applications [5].The first branch composed of triple constituent which design the correlation of potential upon capacitance. This branch has a time constant is approximately in seconds. So 1st section is defined as immediate branch. The 2nd twig of the equivalent circuit comprised of a resistor and capacitance in series which has the time constant in the range of minutes and models the charge redistribution. So the second branch is described as delay branch.

The 3rd branch consists of one parallel leakage resistance Rl, significantly address the self-discharge procedure of the SC. But it is complicate to draft Rl as a dependent on the SC terminal voltage and current [2][5]. Alternative technique is suggested in [1][4], outlining decision of the emf on the capacitors is needed: these, in conjunction with the circuit variables, are resolved with a genetic algorithm, notably in appropriate in a real-time applications.

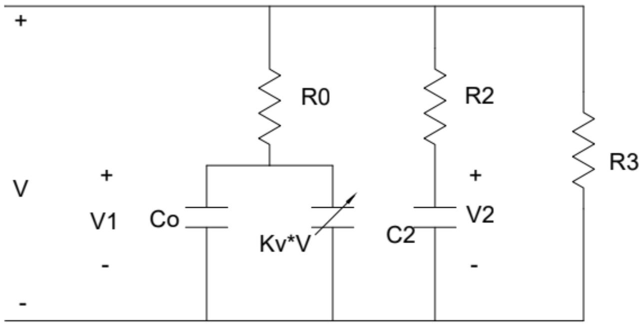

Fig.2 Two branch model of SC

B. Analysis

Fig.2 epitomizes the equivalent 2 branch circuit of the super capacitor. In this, 1st branch contain resistor R0 in series with the parallel combination of the fixed capacitor C0 and variable capacitor which depends on terminal voltage V and the current passing through this arm is i1. 2nd branch is the delay branch which comprises R2 and C2. 3rd branch has leakage resilience R_{lea}. If R0 is neglected, which is appropriate for super capacitors, and Rlea is considered [2][5], then

Total current is given by

$i=i1+i2+i3$ - (1)

The current through main branch is given by

$i1=(c0+2*Kv*V)*dv/dt$ - (2)

The current through delay branch is given by

$i2=C2*dv2/dt$

$i2=C2dv/dt - R2*C2*di/dt + R2*C2*C0*d2v/dt2 + 2*R2*Kv*C2*v*d^2v/dt^2 + 2*R2*Kv*C2*(dv/dt)^2$ - (3)

The current through leakage resistance is given by

$i3= v/R3$ - (4)

So the input current is the function of its terminal voltage and its derivatives

Substituting equations 2,3,4 in 1

$i=(C0+C2)dv/d t- R2*C2*di/dt + R2*C2*C0*d^2v/dt^2 + 2*R2*Kv*C2*v*d^2v/dt^2 + 2*R2*Kv*C2(dv/dt) + v/R3$

$i=(C0+C2)*dv/dt+2Kv*v*dv/dt +T2*C0*d2v/dt2-T2*di/dt + 2*T2*Kv*(v*d^2v/dt^2+(dv/dt)^2) + v/R3$

Where, $T2=R2*C$

V=terminal voltage across the capacitor

This can be written as

$$A\ \alpha \approx b$$

Where

$A=[dv/dt \quad 2v*dv/dt \quad d^2v/dt^2-di/dt \quad (v*d2v/dt2+(dv/dt)2) \quad 1/R3]$

$\alpha 1=C0+C2$

$\alpha\ 2=Kv$

$\alpha 3=T2*C0$

$\alpha 4=T2$

$\alpha 5=T2*Kv$

$\alpha 6=1/R3$

$b=[i]$

Considering the parameters meant to be computed practically, one such most convenient procedures perhaps the Recursive Least Squares (RLS), and this paper trails the computation demonstrated in [7, ch.9].

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III. RECURSIVE LEAST SQUARE ALGORITHM

The recursive least square (RLS) algorithm is a linear adaptive filtering algorithm, which in general, consists of two basic process:

1. A filtering procedure, which includes (a) figuring the yield of a straight channel in reaction to an info sign and (b) creating an estimation mistake by contrasting this output and an ideal reaction.
2. A adaptive procedure, which includes the programmed alteration of the parameters of the channel as per the estimation blunder.

The blend of these two procedures cooperating establishes a criticism circle, as represented in the square outline. To begin with, we have a transversal channel, around which RLS calculation is manufactured; this part is answerable for playing out the filtering procedure. second, we have a system for operating the adaptive control process on the tap weight of the transversal channel[7] consequently the assignment "adaptive weight-control mechanism" in the outline 3.

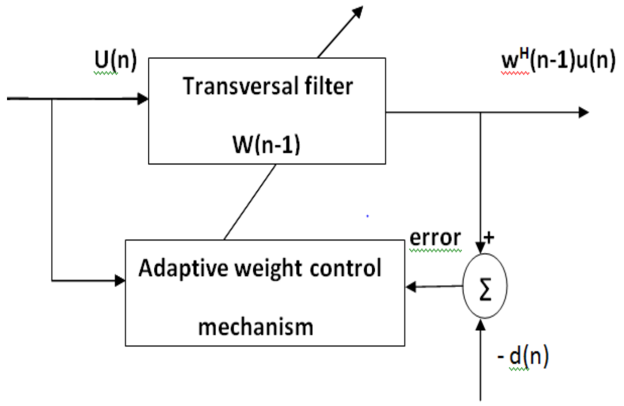

Fig.3 Block diagram of recursive least square technique

For any adaptive algorithm, correlation matrix of the tap inputs u(i) and cross correlation matrix between the tap inputs and the desired output d(i) are necessary.

Here correlation matrix Φ(n) is

$\Phi(n) = \sum_{i=1}^{n} \lambda^{n-i} u(i)u'(i) + \delta\lambda^{n} I$

And cross correlation matrix z(n) is

$z(n) = \sum_{i=1}^{n} \lambda^{n-i} u(i)d(i)$

The relation between these two matrices is

$\Phi(n)\, w(n) = z(n)$

Where w(n) is the tap weight

Recursive equation for maintaining the least square estimate of tap weight w(n)

$w(n) = w(n-1) + k(n)[d^*(n) - u^H(n)w(n-1)]$

$\quad = w(n-1) + K(n)e(n).$

Where K(n) is the gain

IV.SIMULATION AND RESULTS

A. Signal Processing For Estimation Of Parameters Of Sc

Estimating the variables of the SC two arm pattern using the least square technique involves the flow of data in the following fashion ie. the SC terminal voltage and current data has to be filtered and then it is given to the RLS algorithm. Then the parameters are estimated. In this practice, the SC terminal voltage and current data is to be measured using the matlab Simulink for the two-branch model of SC by assuming the parameters ie. Resistance, capacitance values.

The signal flow for the parameter identification of super capacitor is picture in fig 4.

Here filter may be the adaptive filter or FIR filter and differentiator is to differentiate the filtered signal which is given to the RLS algorithm

From the below representation we get α1, α2, α3, α4, α5, α6. Such that the parameters are to be identified

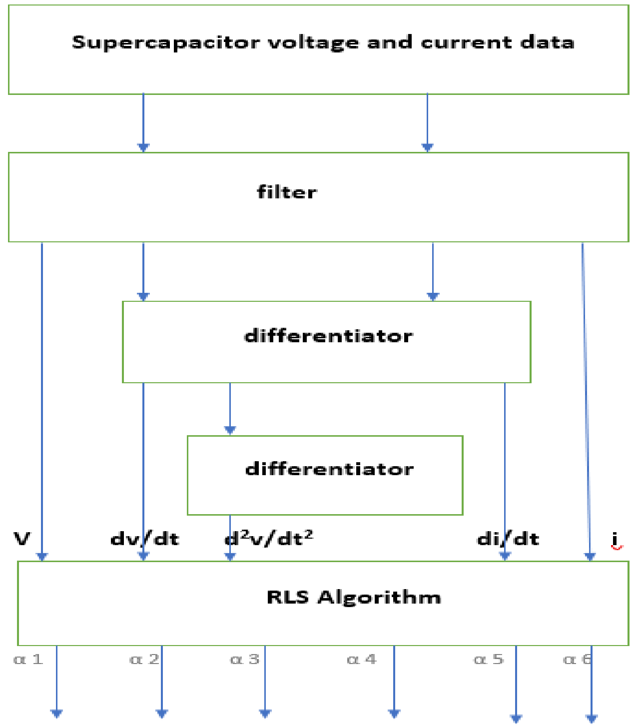

Fig.4 Signal processing for the two branch model parameter identification.

B. Results

The parameters of the two arm pattern are estimated as follows

The first arm has the variable capacitor and that parameter can be estimated as pictured in Fig.5

The second branch has the capacitor C2 and first arm has the capacitor C1. The parameter of C0 + C2 is shown in Fig.6

The third arm has the resistor R3 which is parameterised in graph Fig.7

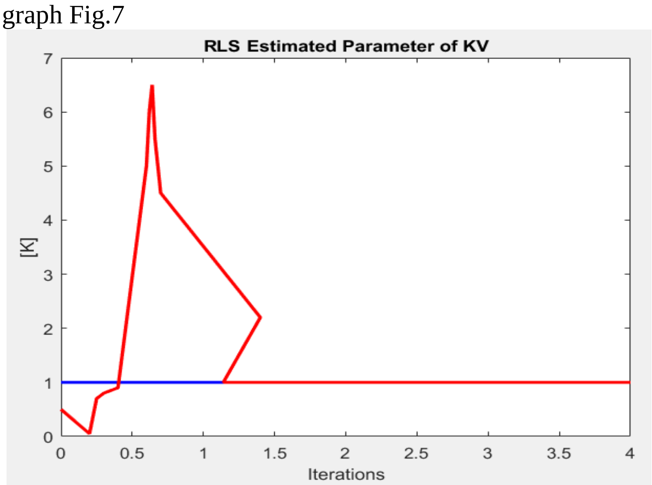

Fig.5 Variation of Kv with iterations of RLS

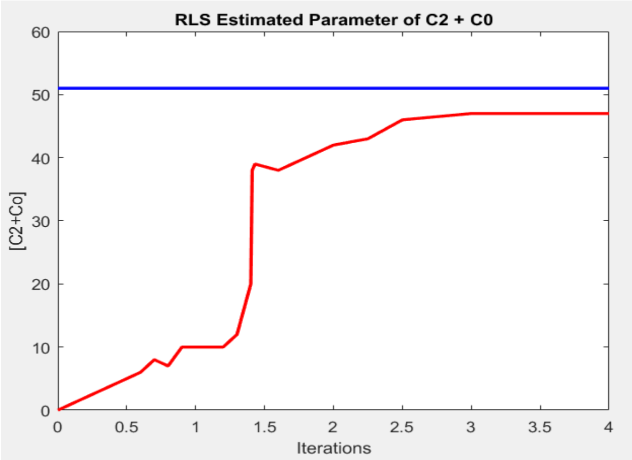

Fig.6 Variation of C0 + C2 with iteration

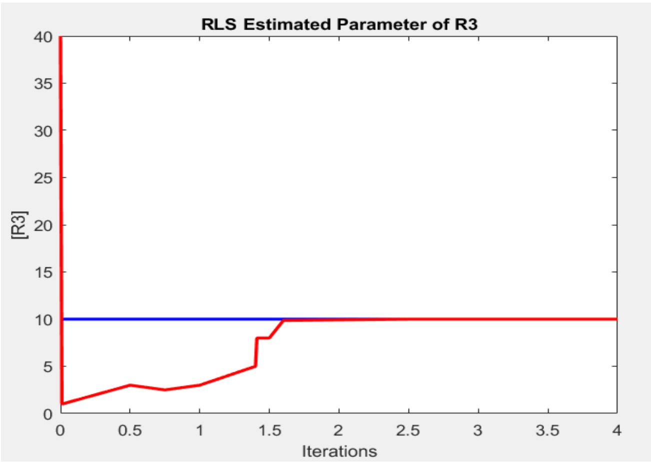

Fig.7 Variation of R3 with iteration

In all the three graphs the ***blue*** line indicate the actual value of the parameter and the ***red*** line is the parameter value estimated using recursive least square technique. This shows that the parameters of the SC are to be estimated almost exactly. So this is the best technique for identification of the parameters.

V. CONCLUSION AND FUTURE SCOPE

A. Conclusion

Super capacitor, storage device like batteries, are designed in numerous patterns. Amongst them two branch model is simple illustration. There are number of methods for the identification of super capacitor. Amongst them least square method is the accurate and easy approach for the identification of two arm model parameters. So parameters are identified accurately for two arm design

B. Future Scope

Utilizing these accurate and intelligent techniques, if the parameters are identified and our devices are equipped with these SC's then the wastage of energy is minimum and also our devices will work more fast. so with the invention of more accurate SC's we foresee the world with less power consumption devices.

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