Empirical System Identification (ESID) and Optimal Control of Lattice-Assisted Nuclear Reactors

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Abstract — Empirically-identified calculations, using Empirical System Identification (ESID), and the actual input electrical power to LANR devices can derive the output. This paper reports investigations of state-vector dimensions n = 3, 50, 30, which indicate that ESID accuracy ranges from 92.2% (n=3) to 93-97.3% (n=5) to 97.7%. (n=30) The ESID system failed to predict "heat after death". This paper also reports that ESID control of LANR may yield a possible Output Power gain of more than 10 dB improvement, augmenting the known 8-14 dB gain from LANR metamaterial technology, and the 14-25 dB gain which results by using Optimum Operating Point (OOP) technology.

Index Terms—Optimal operating point, OOP, lattice assisted nuclear reactions, palladium, empirical system identification, ESID, ESID control

1. Introduction

At ICCF-1, Dr. Robert Bass proposed using ESID technology to discover Hidden State-Vectors and their governing Dynamics in order to design feedback control systems for fusion reactors. The goal was to manipulate the hidden variables to optimize reactor performance. At ICCF-7, Dr. Mitchell Swartz introduced the concept of Optimal Operating Point (OOP) technology (Swartz 1998, 1999; 1992, 1994) as the set of conditions under which the power gain (from output thermal power divided by input electrical power) is optimized. The hypothesis of this paper which we investigated was whether these technologies may have improved efficacy when their complementary approaches are appropriately combined.

2. Experimental

For these experiments, data was obtained from active Phusor® LANR devices producing excess energy, as demonstrated by redundant calorimetry and heat flow measurements.

The data was initially investigated by ESID technology using a hidden state-vector dimension n = 6, and matrices (A,B,C) of sizes respectively 6-by-6, 6-by-1, 1-by-6 based upon a Ho-Kalman-Leverrier algorithm (Bass 2006). This was found to be limited for this LANR work. The identified n = 6 system had poles too near to the boundary of the unit-circle in the complex-frequency plane $|z| = 1$, where the Leverrier algorithm is known to be numerically fragile. Therefore the ESID approach was repeated using the more statistically-sophisticated Canonical Variate Analysis (CVA), and the more numerically robust linear "subspace" approach (Wallace Larimore, Adaptics Inc., ADAPTx).

3. Results – Prediction Accuracy

When ESID analysis was applied to Phusor® and driven appropriately as described elsewhere (Swartz 1997,2006) LANR devices, with the optimal state-vector dimension n = 3, the analysis demonstrated an excess Power Gain of ~175%, in good agreement with the other independent methods which examined the specimen during the preliminary analysis. On reconstruction, the analysis had a rather stunning 92.2% accurate prediction by ADAPTx (Figure 1).

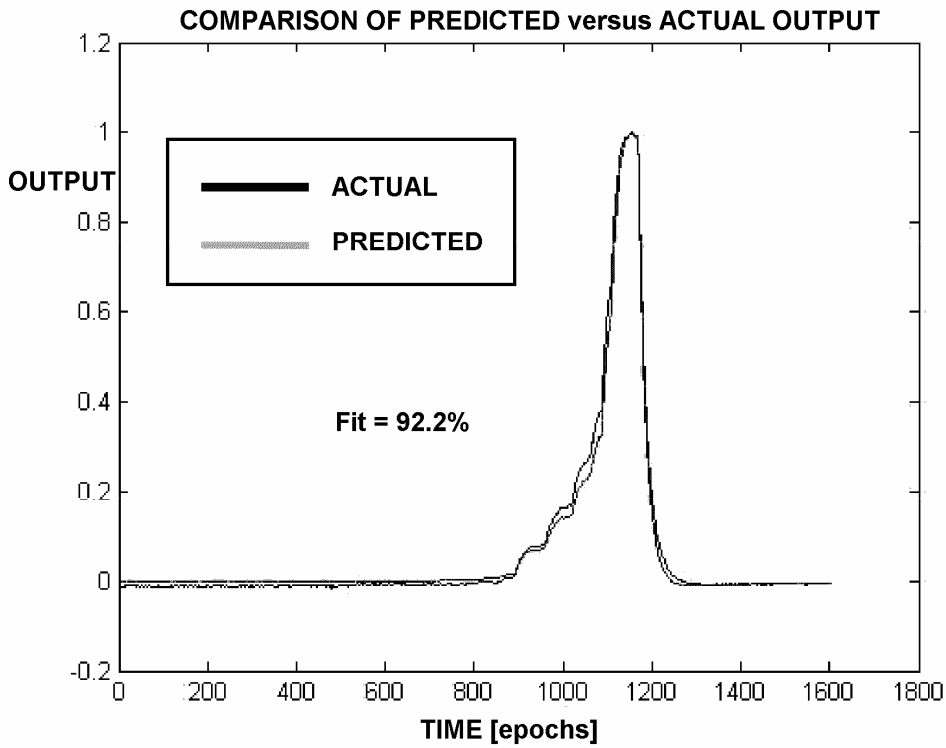

Figure 1. ESID Optimal LANR Control (n=3). ESID Simulation superimposed on Phusor-LANR result for measured accuracy of 92.2%.

Our investigations continued with the optimal state-vector dimension n = 5. The result of the 5-dimensional state-vector and associated (A,B,C,D) used to predict the Output Power from the Input Power on the LHS of the Optimal Operating Point (OOP) segment was a 97% accuracy for the "ascending" initial segment of the data, and likewise a similarly excellent [93% accuracy] n = 5 model for the "descending" part of the data from the Phusor®-type LANR device, for an Output ~33% larger than the Input.

Note that Figure 2 demonstrates that the ESID system failed to predict tardive thermal power, also known as "heat after death" (HAD). HAD occurs after the termination of input electrical power. It is the time integral of the tardive thermal power (Swartz 2006). This is shown by the star (*) in Figure 2.

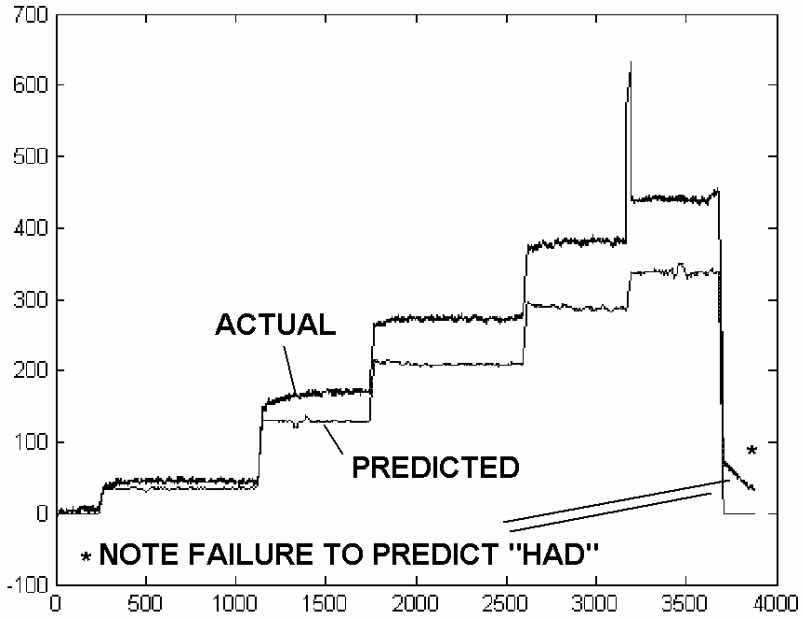

Figure 2. ESID Optimal LANR Control (n=5). ESID Simulation superimposed on Phusor-LANR result for measured accuracy 93-97%.

4. Results - Optimal State Vector Dimension

Our investigations continued into determining the optimal state vector dimension. The "first cut" gave an optimal state-vector dimension of n = 30. There was also an excellent result with n = 5. As Figure 3 shows, the "Balanced Order Reduction" reduction of n from n = 30 to n = 5, degraded the excellence of the fit only in the 3rd decimal place, from 97.7% to 97.3%. At this time, the optimal state vector dimension may be closer to 5 than 30, if computational time limits performance. Attention is directed to Figure 3, which clearly shows that ESID Simulations with state vector dimensions increasing from 5 to 30, has increased measured accuracies increasing from 97.3% to 97.7%. As Figure 3 demonstrates, it is most important in the early response of LANR systems.

5. Results - ESID Controlled Optimal Gain

After converting the n = 5 "ascending" and "descending" models to the same coordinate system, a "final" equilibrium state-vector to the left of the OOP segment, using a "beginning" equilibrium state-vector at the initiation of the "descending" segment on the descending side of the OOP manifold. Both of these states predict that the best achievable further increase by ESID control may be ~33% more Output Power than Input Power.

6. Interpretation and Conclusion

There are several implications. First, empirically-identified calculations and the actual input electrical power can derived the output of LANR devices. ESID technology offers advanced OOP control based on Figure 1, where the "predicted" output, based upon the empirically-identified (A,B,C) and the actual Input alone, is derived (shown by Figures 1,2,3), confirming the potential effectiveness of the principle.

Most interestingly, especially in retrospect, the ESID analysis failed to predict tardive thermal power, or its time integral, "heat after death" (HAD). Note that Figure 2 demonstrates that the ESID system failed to predict tardive thermal power, also known as "heat after death" (HAD). HAD occurs after the termination of input electrical power. It is the time integral of the tardive thermal power (Swartz 2006).

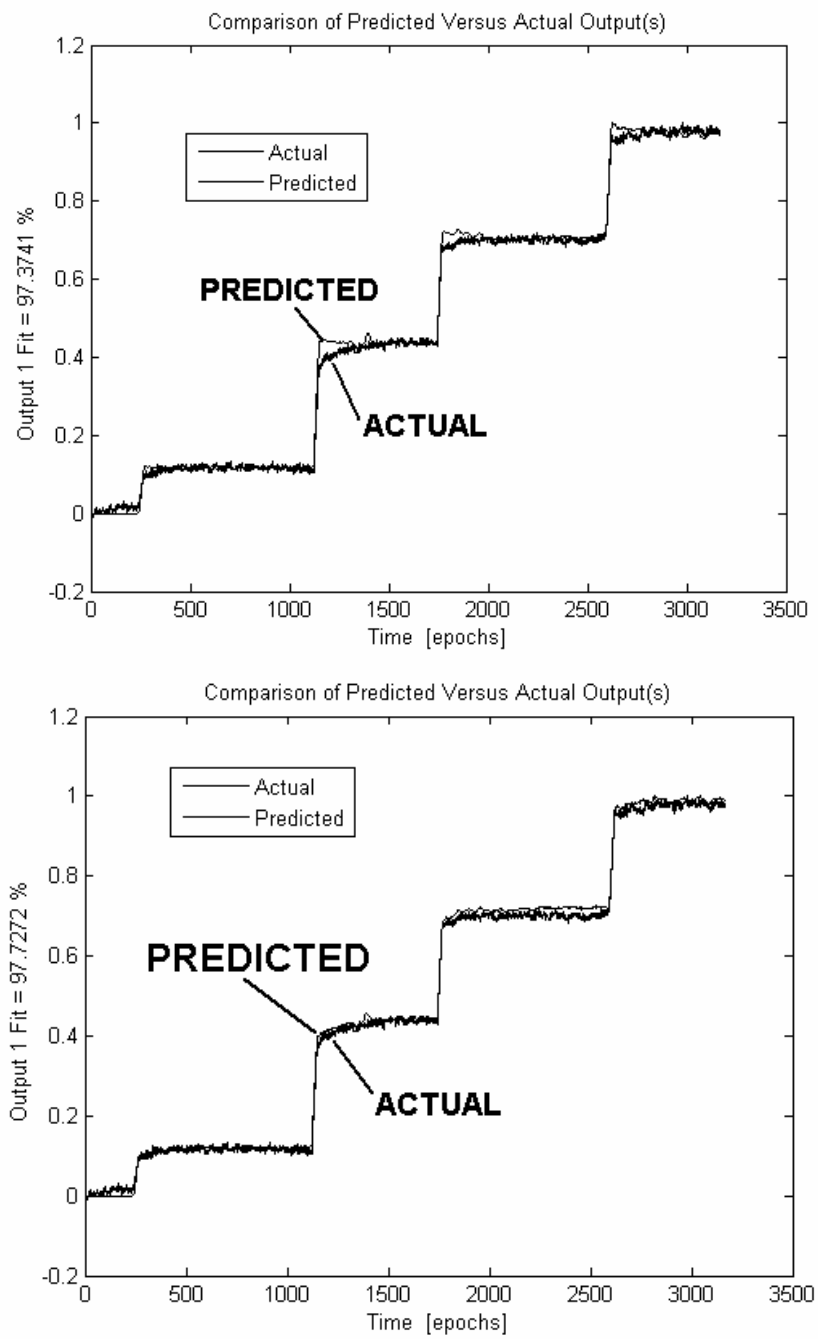

Figure 3. Optimal State Vector Dimension (n=5 and 30)

Second, presently, OOP is found by manual experimentation and proprietary automated techniques. These may be augmented by a Kalman Observer to estimate the state-vector x(k) in real time, and thereby enable the implementation of a State-Feedback Control Law to seek out

the OOP automatically, and subsequently maintain the system operating as near to its OOP as is possible.

Third, however, using controllability theory of Kalman, a very important result has been uncovered. By transfer of both sets of (A,B,C) matrices to the same coordinate system, and computation of the mean value of the 5-dimensional State Vectors on the LHS & the RHS of the JET Phusor® LANR "sweet spot", the putative derived possible power gain might increase if one used optimal state-variables in real time using control theory, such as Kalman's LQR theory, to drive the system to that particular optimal operating point (OOP) state.

Finally, and most importantly, ESID control of LANR yields a possible output power gain of more than 10 dB improvement, augmenting the 8-14 dB gain from LANR metamaterial technology, and the 14-25 dB gain which results by using Optimum Operating Point (OOP) technology.

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