

From Lyapunov to Krylov – My Research Journey

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I.I.T Kanpur 1963-81



- U.S AID Initiative . A consortium of 9 US Univ. , Led by MIT.
- 1963 , IBM 1620 Computer flown from Princeton to Kanpur!**The first educational computer in India.**
- An intense outreach program in Computer Education.
- In Power, Profs El-Abiad and Stanton of Purdue Univ ran a short Course on *Computer Apps in Power Systems*. Big Impact!
- The local State utility started using the Computer and rest of the country followed the model!

Lyapunov Stability work at IITK



- Research goal was to formulate Power system stability problem in a control theoretic framework.
- To compute critical clearing time for a fault, we need a Lyapunov function for the post fault system and compute the region of attraction.
- A 1971 PhD thesis on Lyapunov stability of Power systems was perhaps the starting point! IEEE PWRS Paper!
- Research on many aspects of P.S stability (transfer conductance, modal control, small signal analysis of power systems, vector Lyapunov functions etc).

Research at IITK(Contd)



- Many Control Applications to Power System problems were investigated.
- Work in Model Reduction work was interesting
- Electro-Mechanical distance measure and Singular Perturbation work leading to a PhD thesis.
- Organised an IFAC Conf. on Comp . Apps in Power Systems in New Delhi 1979.

Lyapunov and Transient Energy function(TEF) work at ISU (1979-81)



- Athay & Podmore(EPRI) pioneering work on TEF was a great influence.
- Useful interaction with Aziz Fouad and Tony Michel
- 1981 book on *Power system stability by Lyapunov's method* (N.Holland).
- Read a bench mark paper by Bergen and Hill on structure preserving TEF, useful for the NEW Grid now!

UIUC 1981-2003



- Working with Pete Sauer for two decades!
- Developed the Grad program and research. Wrote a book together. Will be updated soon with Joe Chow!
- Marija initiated work in parallel computation in P.S.
- Grad student inputs were excellent,
- Jennifer Sterling
- Hisham Othman,
- Kash Khorasani,
- Mark Laufenburg,
- Tony Nguyen
- With each student a *new* research area evolved ,all inspired by control or computer orientation

1981-2003 (contd) New Research Areas



- Sec.constrained Preventive Rescheduling(Jennifer)
- Time -scale based energies, Slow and Fast(Kash and Hisham)
- Trajectory sensitivity analysis(TSA) work (Mark)
- Collaboration with visiting Prof Ian Hiskens resulted in bench mark work on TSA for DAE systems with Discrete events. Useful for NEW grid!
- Tony used the work in Preventive Rescheduling, and Distributed Gen.
- Finally comes Krylov!

1981-2003(contd)



- Krylov subspace method for model reduction of power systems inspired by similar work in VLSI simulation.
- Extension to Balanced truncation method by Pete's student Shan Shan Liu offers a new approach to MOR in the New grid
- A new Junior level UG course in *Power Circuits and Electro Mechanics* was developed using the MIT philosophy of Melcher and Woodson.
- Wrote a book for ECE 330, taken by 75% of the entering class!. A matter of great satisfaction

Post 2003 -



- Visiting India and interacting with Power sector people and IT sector.
- Also had collaborative research with visiting scholars from India and Mexico
- Post 2012, interaction with PNNL on projects in Model reduction and Smart Grid.
- Interacting with UCLA in their V2G and Microgrid work
- Helping UC Riverside start a formal power program the first in the UC system, a wish that Late Art Bergen and I tried for a long time!
- UCLA starting an on line program in P.S with focus on the New grid

Final thoughts!



- Looking back it was a great experience to work in India and UIUC! Thanks to George Swenson for his invitation to join UIUC in 1981!
- On the social front, ISU and UIUC, we added three Son-in-Laws to the family, Vijay(ISU), Nikil Dutt and Utpal Dave (UIUC) !!!
- Three of my children plus a grand son (Eknath Vittal in Power) are proud UIUC Alumni and presently two grand daughters are studying here!
- Thanks to everyone who helped organize this memorable event in our lives!
- Thanks to Robin and Joyce for their excellent support