Dean Dr Sudha Balagopalan presents a paper in Malta

Dr Sudha Balagopalan (Dean – Academics) presented a paper, co-authored with Mr S Ravishankar (AP, CSE Dept), in the 9th International Conference on Operations Research and Enterprise Systems (ICORES 2020) held at Valletta, Malta. The presentation, held on 22 February 2020, was in the poster format.

The purpose of the Conference was to bring together researchers, engineers, faculty, and practitioners interested in both theoretical advances and practical applications in the field of operations research. Two simultaneous tracks were being held: one on domain independent methodologies and technologies and the other on practical work developed in specific application areas.

All papers presented at the conference will be available at the SCITEPRESS Digital Library and a short list of revised and extended versions of presented papers will be published by

Springer in a CCIS Series book.

Where is Malta?

Malta is a Southern European island country consisting of an archipelago in the Mediterranean Sea. It lies 80 km south of Italy, 284 km east of Tunisia,and 333 km north of Libya. With a population of about 475,000 over an area of 316 km^2, Malta is the world's tenth smallest and fifth most densely populated sovereign country. Its capital is Valletta, which is the smallest national capital in the European Union by area at 0.8 km^2 (0.31 sq mi). The official and national language is Maltese, which is descended from Sicilian Arabic that developed during the Emirate of Sicily, while English serves as the second official language. (*Wikipedia*)

Power System Optimization Problems

Game Theory Applications

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Abstract

We look at conflicts in power system problems from an optimization angle & use Game Theory (GT) concepts for modelling and solving. To model the conflicts effectively we identify the players, optimizing quantity & the platform. We detail two case studies & more areas where the principles developed hold. We focus on Cooperative GT & extend to Noncooperative GT. Market engineering tools like differential pricing, inverse elasticity rule, graph theoretical allocation etc. are developed to organize the optimization process. We develop 'Power Vectors' used to cede players for decision making and inducing stability. With encouraging results we conclude that both versions of GT are powerful tools for optimization in a practical scenario with conflicts and contradictory incentives.

Introduction

Conflict situations in the electricity market context warrant the need to *compete or cooperate/ negotiate* [1] and choose strategies to maximize benefits via a rational decision making. The apt choice of players, the forced evolution of the 'live' decision variable, the strategic design of information coordination and parameters embedded in the characteristic function influencing/facilitating a conflict-free sharing of benefits make **Cooperative Game Theory** a suitable platform for modelling and solving the problem. Accordingly, crucial market engineering tools are developed to coordinate an optimum set of trades in a non-integrated market where

1. Commercial considerations overpower engineering requirements leading to abuse of power corridors offering 'open access' by the end users in their race for power portfolio acquisition.
2. Asymmetric, distributed information & decision flow & analysis lead to non-integrated operations
3. Inelastic transmission sector though resources are limited & demand is maximum

Main Objectives

We mainly aim to address the conflicts reported in power markets via a CGT platform and specifically

1. To design critical roles for players and rules of the game to reinstate network discipline.
2. To develop the characteristic function as a tool to achieve 'common cause' & penalize deviations.
3. To elasticise the Need Vs. 'Willingness to pay' curve & incentivise commerce
4. To integrate operations via coalitions where partners are identified via a powerful tool & thereby address distributed and asymmetric information
5. To develop CGT tools to strengthen the Pay-off vector as an onus of making a choice

Materials and Methods

The 4 stage algorithm of CGT based modelling and organizing optimized solutions is given in Fig. 1.

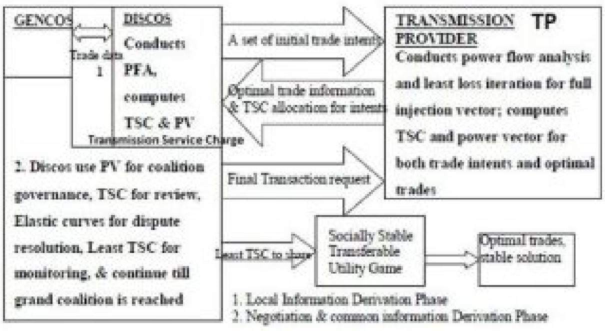

Figure 1: Coordinating Optimal trades via CGT

Mathematical Section

The 3 tools designed are as follows:

TSC is designed as a quadratic for optimizing; as a tool to set the rules of the road by the TP; it penalizes loss, congestion, too much power shuttling over corridors (3-5 times demand committed) where q signifies loss, z line flows & a, b, c, d suitable weights for penalizing elements of unwanted transactions

$$P(q) = aq^2 + b\Sigma_{lines}z + d\Sigma_{congested}z + c \tag{1}$$

Such a construct enables development of elasticity of demand as a tool in the inelastic open access transmission sector; as an enabler to differential Pricing; follows Inverse Elasticity Rule; taxes differentially deviations from the lowest TSC for individual or coalitional combination of trades as demonstrated in Fig.2.

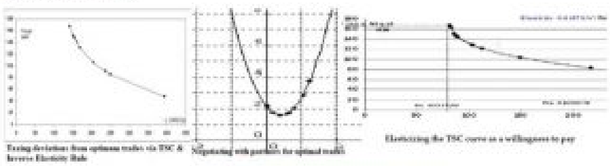

Figure 2: TSC: Elasticizing, inverse price rule, Sharing

Once the best possible TSC figures are released by TP, the Discos use local information to contact coalition partners for a win-win TSC share. The Power vectors(PV) computed as below enable partnering with agents who increase their own trade volumes but at low TSC, by causing counter-flows.

$$fP(A) = \frac{1}{n}j - \frac{1}{n}T^{A^-}1s^A \tag{2}$$

Here T^A is the adjacency matrix of A with $t_{ij} = 1$ if (i, j) is a arc of A & s^A is the score / no. of successors of each node.

Results

The algorithm with the tools are applied to a 5 bus ring main 165 MW & a 24 bus, radial, 1215MW real systems; the results are tabulated.

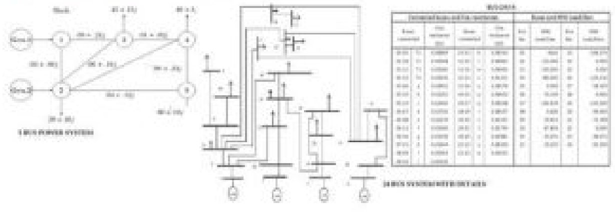

Figure 3: 2 Case studies

Outcomes of the application	5 Bus	24 Bus
Total loss q	From 2.89% to 0.97%	0.562
$\Sigma_{lines}z$	From 160% to 99.2%	From 313.8% to 171
Congestion	From 69.5% to 28% on 2 lines	From 260% to 78.9% on 5 lines
Reallocated trades	Optimal	Optimal

Table 1: Table caption

Another GT application is the Transmission charge sharing as per algorithm design in Fig. 4 for obtaining a Socially Statble Transferable Utility Core [2] (SSTU) as solution space. Figure also shows a comparison between some available methods. The real time withdrawals are prevented because of the endogenous parameters used in the power vector.

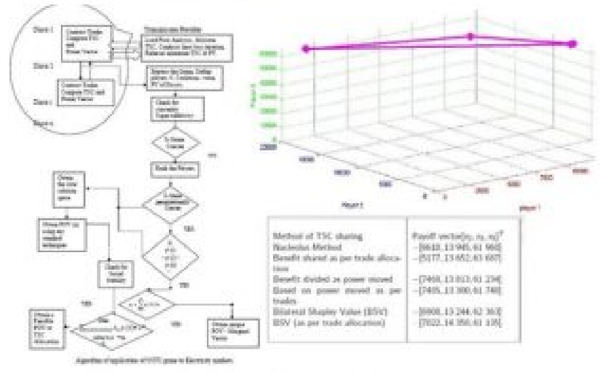

Figure 4: Transmission Price sharing via the SSTU algorithm

Conclusions

- Appropriate Game Theory applications with additional tools can model & solve power system problems in conflict situations.
- Optimally islanding the faulted power system and thereafter judicial restorations are optimization problems which can be adequately resolved using GT.
- Power vector is a powerful tool which can be used to resolve information deficiency and consequent uncertainties in social problems also.
- Differential pricing can be optimally applied to address market problems including volatility.
- Operation, cost sharing, impact resolution, tackling fungibles etc. are all outcomes of 'choices' made and negotiations and hence more acceptable.

References

1 Sudha Balagopalan. *Development of an Integrated Model for Transmission Sector in Electricity Markets*. National Institute of Technology, Calicut, 2011.

2 G van Der Laan Herings PJJ and Talman D. The Socially stable core in Structured Transferable utility games. *Games and Economic Behaviour*, 59, 2007.


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