Pricing Transmission Rights using Ant Colony Optimization

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ABSTRACT

We propose a novel idea for pricing Transmission Rights (which are similar to financial options) using a nature inspired meta heuristic algorithm, Ant Colony Optimization (ACO). ACO has been used extensively in combinatorial optimization problems and recently in dynamic applications such as mobile ad-hoc networks. Specifically, the proposed ACO algorithm have been applied to totally different application, Transmission Rights, in the current study.

Categories and Subject Descriptors

I.2.8 [**Artificial Intelligence General**]: Graph and Tree search strategies—*Optimization Problems*

General Terms

Algorithms

Keywords

Ant Colony Optimization, Transmission Rights, Options

1. INTRODUCTION

The price of electricity in the wholesale market can be extremely volatile at times of peak demand and supply shortages. Due to the substantial price and volume risks that the markets can exhibit, financial risk management is often a high priority for participants in deregulated electricity markets.

Hedging is one of the techniques designed to reduce or eliminate financial risk [1]. A good example for hedging could be for participants to take two opposite positions that will offset each other if prices fluctuate and the investment remains risk-neutral. Many hedging arrangements, such as swing contracts, Virtual Bidding, Financial Transmission Rights, Options (Call or Put) are traded in sophisticated electricity markets. In general, they are designed to transfer financial risks between participants. We study transmission rights in electricity market and propose a Ant Colony Optimization (ACO) based algorithm to price them.

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2. TRANSMISSION RIGHTS

Interties are transmission lines that allow electricity to move between neighbouring areas. Intertie trading involves a financial risk. Transmission rights (TRs) help in this risk management. They provide a financial hedge for electricity traders who trade on interties to recover money lost. TRs can also be used as speculative investments by market participants. For example, in Ontario, Canada, TR market is open to any company that chooses to join Independent Electricity System Operator (IESO) [2] administered market. TR payments are based on congestion on transmission lines.

Congestion occurs when the quantity of economic offers or bids exceeds the physical transfer capability of the intertie. That is, although the transmission lines are loaded at full capacity, they are unable to serve all of its waiting customers. The reasons for this transmission inability may be due to unanticipated conditions, equipment outages or system security requirements. Ontario's electricity market has uniform energy market price. However, each of the intertie zones may have a different settlement price. This difference in settlement price is caused by congestion on the interties.

All transmission rights are auctioned for each intertie path, and are directional. The path indicates the injection and withdrawal zone. For example, IESO will have separate TR auctions for Michigan, USA to Ontario and Ontario to Michigan, USA. TRs are sold through a bidding auction and prospective TR owners submit bids to purchase TRs. There are two types of TR: long term TR guarantee the winning participant ownership of TR for a specific path for one year while short term TR guarantee ownership for one month. TR owners have a right to revenue based on the number of rights they hold and the spot market price differences between external zones and Ontario (interties). TRs pay the holder the price difference regardless of the physical energy traded or the congestion pay-out collected. It is to be noted that TRs are only financial instruments and do not provide the holder any guarantee for the physical transmission of energy. So, they do not have any effect on real time scheduling of transactions in the market.

All transmission rights are sold in one megawatt (MW) increments. One TR represents one megawatt of energy on a given path on an intertie.

3. MAPPING TR TO FINANCIAL OPTION

An *option* is a contract in which the buyer (*holder* of an

option) has the right but no obligation to buy (*call* option) or sell (*put* option) an underlying asset (for example, a stock) at a predetermined price (*strike price*) on or before a specified date (*expiration date*). The seller (also known as *writer*) has the obligation to honor the terms specified in the option contract. The holder pays a premium to the writer (see for example [1]).

In case of TRs, IESO is the writer and any market participant can be a holder of the contract. For example, a market participant can hold 50 TRs for 1 month on Michigan to Ontario path.

3.1 Application of ACO to price TRs in Electricity Market

ACO is a metaheuristic based on the foraging behaviour of ants. These ants collaborate through stigmergic principles to build solution to an optimization problem.

ACO [4] have been used to solve option pricing problem. To the best of our knowledge, there is no work reported in the literature on the use of ACO for pricing TRs. Our goals for this study are (i) to confirm the suitability of ACO for Transmission Rights; (ii) identifying/computing the estimated premium for TRs written as an option under given constraints; and (iii) expediting the pricing strategy with parallel computing. In this LBA, we have not discussed TR premium.

The following arguments about electricity market brings out it's similarities with ant world and hence applicability of ACO for pricing TRs. Participants holding TR look for congestion on transmission line in order to maximize profit with smallest investment as ants look for the shortest route to the food source to biggest food source. The electricity market participants and ants have no central control and are directed by individual market participant's activity and pheromone in ants. In the deregulated electricity market, individual transactions (buy/sell) by each market participants (local interactions) lead to emergence of market behaviour which is similar to the local interactions between ants leading to emergence of global behaviour.

ACO algorithm to price transmission rights uses a random acyclic graph, G=(V,E) where V is the number of vertices and E is the number of edges. An investor cannot go back in time, and rethink their decision. Therefore, we assume an acyclic graph to reflect our problem. Ants wander on this graph moving from node to node. Each node stores an asset price and each edge represents the transition from one stock value to another. In the algorithm, ants deposit pheromone on the paths while following the paths based on probability of pheromone deposited previously. Paths which are not reinforced by ants lose their pheromone concentration (evaporation). At the end of the algorithm, the path with the highest pheromone concentration is the optimum solution. These are our initial thoughts on pricing transmission rights. We are looking forward to further enhance our ideas and applying our knowledge in TR pricing using nature inspired algorithms. Although there are many similar characteristics between an option and a TR, we still face challenges, which would require us to customize and redesign ACO based algorithm for TR problem.

4. PRELIMINARY RESULTS

All experiments were done on a cluster available on the West Grid Consortium [3] using OpenMP. The scheduling policy for shared memory nodes were followed as stated on WestGrid's website during the experiments. As the number of time steps increase, there is an increase in execution time. This is expected, since the amount of computation increases. Increasing the time steps refers to ants searching the solution space in finer steps. In general, increasing the search would result in finding the best possible premium for a TR to buy or sell. Since, we have implemented our algorithm in a cluster available in WestGrid, the execution times are very small. Hence, the investor will be able to simulate many scenarios with different parameters in a small time before deciding on auction price for a TR. Varying volatility can help in simulating all types of scenarios such as peak hours or seasons (when volatility is high) of off peak hours or seasons (when volatility is on lower side). Varying volatility does not change the execution time as the number of steps or solution space remains same. It does, however, increase option values (though not shown in this LBA). These experiments were done under the resident scheduling policy of the grid's resource manager. The timing results could be improved by employing task matching algorithms using nature-inspired approaches such as [5].

Table 1: Time Steps versus Execution Time

Time Steps	1024	2048	4096
Execution Time (ms)	19.63	40.21	102.3

Table 2: Volatility versus Execution Time

Volatility	40%	60%	80%	90%
Execution Time (ms)	40.23	40.18	38.95	39.28

5. CONCLUSIONS

In this research, we have proposed a ACO based algorithm for transmission rights problem. Our algorithm searches the solution space to price transmission right. The approach with ants explore the solution space using pheromone to achieve the goal. The preliminary set of results indicate that the ACO algorithm is likely suitable for transmission rights problem.

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