Using Reputation to Improve Partner Selection in a Smart Grid Environment

Luciano M. Rosset, Luis G. Nardin, Jaime S. Sichman
Laboratório de Técnicas Inteligentes (LTI)
Escola Politécnica (EP) – Universidade de São Paulo (USP)
São Paulo, Brasil
{*luciano.rosset,luis.nardin*}*@usp.br, jaime.sichman@poli.usp.br*

***Abstract*—Sociotechnical systems, such as Smart Grid (SG), require tackling the technological and social aspects complexity in an integrated fashion. The Power TAC simulation platform has been proposed as a realistic model of a Smart Grid retail power market intending to lower the risk of modeling and testing market designs and other policy options for the energy market. Although providing a detailed representation of the technical aspects of an SG, the prosumers' partner selection focuses exclusively on economic aspects lacking a better support of social features. Hence, we propose the use of reputation for the improvement of this selection process. Our preliminary results show that the use of a simple reputation mechanism integrated to the prosumers' decision process improve the selection of the most trustworthy among the competing brokers.**

***Keywords*-Smart Grid; Reputation; Agent-Based Simulation**

I. Introduction

Human society is increasingly becoming more dependent on information technology in order to expand its social capabilities in dealing with complex environments. This is transforming the way individuals interact among themselves and with the world, making interactions migrate from physical environments to sociotechnical systems (STSs).

STSs are cyber-physical systems designed to mediate interactions of two or more autonomous parties or technical elements through the use of information technologies [16, 18]. The term "sociotechnical" thereby refers to the interrelatedness of social and technical aspects of a system, and as it highlights, in these systems technological and social complexity need to be tackled in an integrated fashion [4, 5].

An example of STS is *Smart Grid* (SG). SG is an electrical power grid that supports bi-directional flows of electricity and information between all network nodes, such as power plants and appliances. Accordingly, energy users (i.e., *prosumers*) are not only allowed to consume energy, but also to generate and trade the excess generated. Additionally, the SG also enables real-time market transactions and seamless interfaces between people, buildings, industrial plants, generation facilities and the electrical network [3, 17].

Rathnayaka et al. [13] outline that a seamlessly SG depends on a combination of several factors: (i) smart energy and information infrastructure, (ii) bidirectional communication subsystems among smart infrastructure, (iii) management and control functions, (iv) laws and standards, and (v) prosumers management.

To address some of these factors, Ketter et al. [7] have proposed the Power TAC (Power Trading Agent Competition) agent-based simulation platform of retail power markets that aims at enabling the evaluation of (i) a range of market-based approaches, and (ii) the effective participants management in these markets. The platform contains agents representing realistic models of energy prosumers (consumers and producers), brokers and markets, along with environmental aspects, such as weather, that affect energy production and consumption.

Although providing a comprehensive and detailed representation of the technical aspects of an SG environment, the Power TAC still lacks a better support for the social aspects reported as essential in the context of STSs. To illustrate this drawback, the prosumers decision of whom to buy energy from is only based on economic aspects disregarding completely any other aspects involved in the formation of such partnership.

Hence, we improve the PowerTAC's prosumer agent by (i) including a simple reputation mechanism to its architecture and (ii) enhancing its partner selection decision-making in order to take into account the brokers' reputation as a trustworthy energy contractor. The reputation mechanism enables the prosumers to evaluate their experience with the brokers and use the evaluation to decide whom to select as a supplier in the future. The prosumer updates positively a brokers' reputation if the supplying contract remains unchanged until the committed expiration date, and negatively, if the broker changes the price or revoke the contract before the committed expiration date.

Although simple, the use of the notion of reputation in the prosumers' decision process is a first step to enrich the Power TAC simulation platform with the missing social aspects identified as essential in STSs. Hence, we hypothesize that the use of reputation enables the selection of the most trustworthy among the competing brokers.

The paper unfolds as follows. In Section II, we describe the Power TAC simulation platform. Next, we briefly describe the notion of reputation the perspective of multiagent systems (MAS). We then describe the simple reputation mechanism used to generate the reputation value of interacting brokers and how its value was integrated to the decision-making of the Power TAC prosumer agents. The description of a preliminary experiment and its results are presented in Section V. Finally, we provide some conclusions as well as some ideas for future work in Section VI.

II. PowerTAC

Power TAC [7] is an agent-based simulation platform that represents the high complexity of the energy generation, consumption, distribution and market mechanisms prevailing in an SG environment. It aims at being a low-risk means for modeling and testing market designs and other policy options for the energy market [7]. This platform represents a comprehensive and detailed SG model build as a set of independent entities corresponding to the necessary elements required for represent a real SG operation.

Figure 1 shows the main entities comprising the Power TAC model.

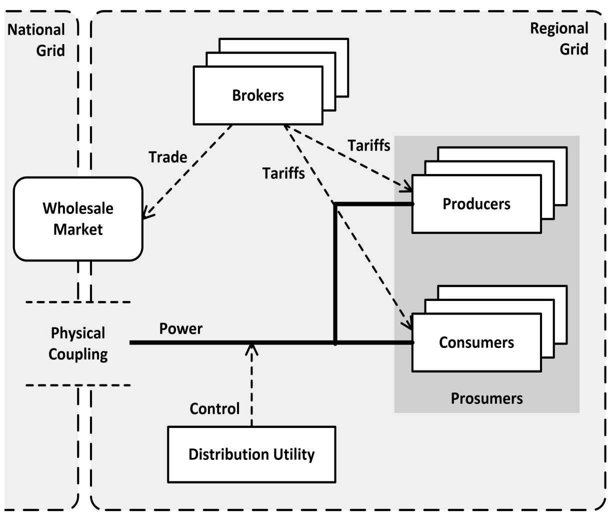


Figure 1. Main entities of the Power TAC simulation model.

Prosumers are households and organizations that can both generate and consume energy. Depending on the prosumer's energy generation and consumption, it can be a *Producer* or a *Consumer*. A producer is a prosumer that generates more energy than it consumes and sells the surplus in the market. A consumer, on the other hand, is a prosumer that generates less energy than it consumes requiring to contract energy supplying services in the market. Prosumer models represent a variety of entities such as households, small and large businesses, multi-residential buildings, wind parks, solar panel owners, and electric vehicle owners.

Brokers are business entities that offer energy services to prosumers (i.e., consumers and producers) by operating a portfolio of *tariffs* (i.e., contracts of energy trading). They are also responsible for balancing the supply and demand within their portfolio by trading energy in the retail market (i.e., market in which prosumers are able to choose among tariff offers from competing brokers) and in the *wholesale market*.

The wholesale market is an entity in which brokers trade energy for future delivery. It is through this market that the *distribution utility* offers energy by a "default" tariff independently of the generation and consumption capacity of the prosumers. The distribution utility represents a regulated electric utility entity that owns and operates (i.e., controls) the energy distribution infrastructure. It is responsible for balancing the supply and demand of energy in the whole system.

The Power TAC platform[1] is used for a competitive simulation of future retail electric power markets in which each competitor implements a broker agent [8]. Brokers compete among themselves aiming at maximizing their profit by trading energy in the retail and wholesale market through the offering of tariffs correspondent to contracts. In addition to design and offer tariffs (i.e., supplying and selling energy contracts), the broker may also modify existing tariffs or revoke them. There are several types of tariffs available in the platform that have some structural information in common, such as (i) the energy price, (ii) the amount of energy traded, (iii) the expiration date of the contract, and (iv) the fine inflicted to prosumers that break a contract prior to its expiration (disregarded in case the broker modify or revoke the tariff before the expiration deadline). The energy price offered by a broker usually depends on how well the broker can use the weather forecast to predict the demand for energy in the future.

The prosumers are provided in the platform and they can be of different types, such as households, office buildings and factories. Each prosumer can have different number of appliances and inhabitants with different activities schedules, which combined with the weather information, define the prosumer's energy consumption. Moreover, the energy generation is also impacted by the weather, which renders it unpredictable, and may force the prosumer to buy more or less energy than expected.

Prosumers actively participate in the market by periodically evaluating tariffs offered by different brokers. The key part of the prosumer evaluation is based on economic aspects of the tariff by calculating the expected cost or gain over the lifetime of the partnership with the broker. The tariff utility is computed as a function of several information [8]: (i) per-kWh payments related to estimated consumption or production, (ii) fixed periodic payments, and (iii) one-time sign-up and early-withdrawal fees or bonuses.

Because humans are not entirely rational, the prosumers' tariff choice follows a probabilistic rather than a deterministic choice. The prosumers use the logit choice model to assign a probability to each tariff t_i of all tariffs (T, where

[1] http://www.powertac.org

$t_i \in T$) utility (u_i) computed according to Equation 1.

$$P_i = \frac{e^{\lambda u_i}}{\sum_{t \in T} e^{\lambda u_t}} \quad (1)$$

The parameter λ is a measure for how rationally the prosumer chooses tariffs: $\lambda = 0$ represents random, irrational choice, while $\lambda = \infty$ represents perfectly rational prosumers always choosing the tariff with the highest utility.

III. Notions of Reputation

Reputation refers, on one hand, to an evaluative belief an agent has about other agents (*social property*). On the other hand, it refers to the result of these beliefs transmission (*social process*) [2].

Reputation is used as a means to discourage unwanted and promote desired behaviors among agents in MAS [1, 2, 6, 9, 11, 14, 15, 19][2]. According to Mui [10, p. 20], trading partners benefit from reputation because it reduces the information asymmetries, which facilitate trusting trading relationships.

Conte and Paolucci [2] propose a cognitive reputation model in which they propose the distinction between two concepts, *image* and *reputation*.

Image refers to directly acquired evaluative beliefs about other agents; whilst reputation is a shared evaluation the social group has about an agent. Both can be used to identify agents that out- or under-performed in previous interactions, respectively, favoring and disfavoring their selection as a future transaction partner. However, image requires a much longer learning curve than reputation as the former depends on direct interactions between the evaluator and the target agent. Conversely, the reputation can benefit from a large set of interactions with the target agent, which may speed the learning process.

IV. Implementation

To fulfill the objectives of this work, the implementation was comprised of two stages: (1) the integration of a simple reputation mechanism to the PowerTAC prosumer's agent architecture, and (2) the enhancement of its partner selection decision process in order to take into account the broker's reputation.

The reputation is a continuous value in the domain $[0, 1]$ assigned by the prosumers to each broker they had some direct interaction with (broker's image). It is assumed that the value 0 refers to the lowest reputation value and 1 to the highest reputation value, as the reputation value corresponds to the proportion of successful expired contracts that the prosumer had with the broker. A successful expired contract corresponds to a contract that has not been changed or revoked by the broker before the expiration date specified, while a unsuccessful interaction is the opposite.

[2]For a comprehensive review on reputation computational models see [12].

This simple reputation mechanism was then integrated to the prosumers architecture and the reputation value used in the partner (i.e., tariff) selection decision process of the *household* prosumer type. The changes were specifically done in the methods *evaluateTariffs* and *evaluateAlternativeTariffs* in the class *Tariff Evaluator*, which are called to handle the evaluation of new and changed tariffs provided by the brokers.

Previously, the tariff utility was calculated based only on economical aspects of the new tariff, which synthetically corresponds to energy total cost (i.e., energy cost plus withdraw fine plus sign up payment) reduced by the inconvenience of changing tariff (i.e., pay fine).

We have changed the calculation dividing the energy total cost by the broker's reputation, which means that the latter is increased proportionally to the reputation value of the broker. It thus reduces the tariff utility consequently decreasing the probability of the broker' selection.

V. Experiments and Results

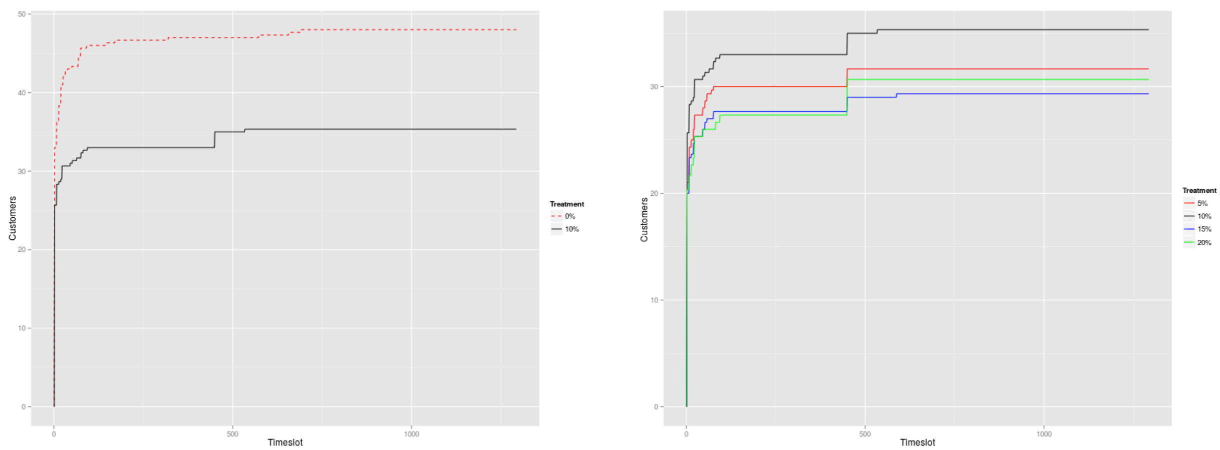
In this section, we investigate the effects of reputation in the partnership selection in an SG by performing a simulation experiment using the modified version of Power TAC as presented in Section IV.

The simulation experiment includes two treatments that differ depending on the number of brokers and their respective probabilities to revoke a non-expired contract (i.e., tariff). In the first treatment, the simulation was performed with two brokers that arbitrarily revoke contracts with a probability of 0% and 10%. It means that one of the brokers never revoke a contract, while the other has a probability to revoke non-expired contracts in 10% of the time. In the second treatment, the simulation was performed with four brokers that arbitrarily revoke contracts with a probability 5%, 10%, 15% and 20%.

Each treatment was run 3 times for 1440 time steps with the Power TAC standard configuration. The analyses of these treatments are based on the mean value of the number of customers assigned to each broker during the simulation.

Figure 2 shows the number of active customers (prosumers) per broker. A possible reason for the observed stable number of clients is that the initial broker's reputation (before any contract is made with it) was set to 50%. This leads to a situation in which, unless the first broker contracted by the client breaks 50% of the contracts or more, the other brokers will always seem less trustworthy.

Additionally, analyzing these graphics, we can clearly identify that in Treatment 1 the use of reputation benefited the broker that does not revoke non-expired contracts. However, such benefit is not observed in Treatment 2 as the broker that revokes contracts with probability of 10% is more successful in attracting prosumers than the others.



(a) Treatment 1: Brokers with revoke probability of 0% and 10%.

(b) Treatment 2: Brokers with revoke probability of 5%, 10%, 15% and 20%.

Figure 2. Dynamic of the number of customers per broker.

Despite appearing inconsistent on a first analysis, these results make sense when correlated to the standard Power TAC configuration. In this configuration only a fraction of the prosumers (i.e., the households) that accounted for the brokers' reputation in order to select a tariff. Therefore, only part of the prosumers would avoid future interactions with brokers that revoke non-expired contracts.

VI. Conclusions

This paper presents a first attempt to improve the prosumer agents in the Power TAC agent-based simulation platform in order for them to take into account the reputation of the brokers when selecting a trading partner. The reputation mechanism implemented was very simple, the preliminary results show that the use of reputation integrated to the prosumers' decision process may improve the selection of the most trustworthy among the competing brokers as hypothesized.

In future work, we intend to tackle these simulation experiment design issues in order to better check the proposed hypothesis. Additionally, we may enable the prosumers to communicate about their reputation evaluations, which may require a topological structuring of the social network connecting them. We also may test different reputation models in order to identify whether there is any performance difference among them in an SG domain.

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