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ANALYSIS OF A CONFLICT ON THE REGULATORY FRAMEWORK OF THE SOLAR DISTRIBUTED GENERATION IN BRAZIL

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RESUMO

O presente trabalho tem como objetivo auxiliar no esclarecimento do conflito entre usuários/produtores de energia fotovoltaica e a agência reguladora do setor elétrico brasileiro (ANEEL). Isso foi feito aplicando o Modelo de Grafo para Resolução de Conflitos (GMCR) com auxílio do software GMCR +. A disputa envolve dois atores e uma questão central: o possível fim dos incentivos ao desenvolvimento da energia fotovoltaica no Brasil, pela ANEEL, e as desvantagens que causaria àqueles que já haviam investido nela. Foram traçadas opções de ações e estimadas preferências para cada DM e, com isso, foram encontrados conceitos de solução para o conflito. Além disso, uma análise inversa foi realizada para identificar como melhores resultados poderiam ser alcançados.

PALAVRAS CHAVE. Resolução de conflitos. O modelo de grafo para resolução de conflitos. Quadro regulamentar.

Tópicos: AdP&ED - PO na administração pública e educação, EN - PO na área de energia

ABSTRACT

The present work aims to help clarifying the conflict between photovoltaic energy users/producers and the regulatory agency of the Brazilian electricity sector (ANEEL). This was done by applying the Graph Model for Conflict Resolution (GMCR) with the aid of GMCR+ software. The dispute involves two actors and one central issue: the possible end of incentives for the development of photovoltaic energy in Brazil, by ANEEL, and the downsides it would cause to the ones that had already invested in it. Options of actions were drawn and preferences estimated for each DM and, with that, solution concepts were found for the conflict. Furthermore, an inverse analysis was carried out to identify how better outcomes could be reached.

KEYWORDS. Conflict resolution. The graph model for conflict resolution. Regulatory framework.

Paper topics: AdP&ED – OR in public administration and education, EN – OR in energy area

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1. Introduction

In the past few years, the field of green energies has shown advances in a pace worthy of attention; the worries of climate change, sustainability, advances in technology, among other things, have pushed their development forward. While this progress is true for many types of renewable energy, one that has seen remarkably quick development is solar energy [IEA 2019].

Each year, new price reductions, rankings and production capacity estimates are reached. Photovoltaic energy is said to have the greatest growth potential over the coming future and, in this scenery, Brazil is one of the countries with the highest potential for photovoltaic power generation. With this in mind, it is very important to give support to the development of this type of energy in order to make it more competitive against conventional forms of electricity production [REN21 2019].

According to The International Renewable Energy Agency (IRENA) [2020], the usage of solar cells to harness electric energy from the sun, through the photovoltaic effect, is a clean, renewable and sustainable way to generate electricity. In addition, it helps to improve some socio-economic aspects by fostering new knowledge generation, job creation, improvements of technologies and innovation for companies and the population.

Nowadays, the Brazilian electric matrix has nearly 80% of its sources from renewable origins, virtually 1,4% (around 2400MW) of it comes from solar centralized power, which places this source as the 7th largest power supply in the country [Brasil 2020]. Yet, these numbers do not include micro (systems with the installed potential of 75kW or less) and mini distributed generation (systems with the installed potential between 75kW and 5MW), which by the end of 2019 totalized about 1600 MW of operational installed power [Absolar, 2019].

This position was made possible due to the many supporting initiatives implemented by the government over the last decade. Some resolutions, like REN n° 482 [2012], REN n° 517 [2012b], REN 687 [2015] and REN 786 [2017], established directives for the micro and mini distributed generation of solar energy, specifically for the energy compensation system – net-metering (system by which the surplus energy generated by a unit can be injected into the distributor's network, the unit will then receive an energy credit (kWh) to be used to reduce consumption costs when the photovoltaic generation is not enough and it has to feed in from the distributor's network).

Furthermore, agreements made with the National Finance Policy Council (CONFAZ) came to exempt various equipment for the generation of solar energy from the tax on circulation of goods and services (ICMS), as is the case of the agreement n° 101 [1997], and n° 16 [2015] which exempts participating states from the same tax, but this time over the energy injected into the network.

Notwithstanding all the support provided in the past, recently, the Brazilian Electric Energy Agency (ANEEL) has conducted a public consultation with the intention of reviewing the rules of the so-called distributed generation (DG). This review has been proposed because individuals that do not own this technology argue that the incentives end up damaging them and require the regulator to take action. Thus, one of the main problems encountered today refers to the conflict between users/producers and the regulatory agency [Baptista 2019].

With regards to this topic, the literature shows that it is nothing new and is full of case studies involving conflicts in many different areas and diverse approaches to resolve them. One of these approaches that have been vastly used to strategically analyze conflicts is the Graph Model for Conflict (GMCR). Silva et al. [2019] make use of this model when analyzing a local development conflict which one of the decision-makers is a regulatory

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body; Garcia et al. [2016] evaluate an energy related conflict that has the participation of provincial governments; and Li et al. [2016] analyze conflicts in the financial field involving commercial banks, local governments and the central government of China, which has the power to regulate and control the credit markets.

From the observation of conflicting interests between two parties and the relevancy of the context, the present study is justified. This conflict brings negative consequences because it stalls the development, deployment and usage of solar photovoltaic technology. This way, apart from the country having a lesser competitive and diversified energy sector, it does not go in the direction of becoming more eco-friendly. Additionally, it lags on complying with the ambitious goals present in the Paris Agreement, which Brazil took part in.

All things considered, the aim of this study is to help clarify the conflict between photovoltaic users/producers and the regulatory agency of the Brazilian electricity sector (ANEEL); and thus, bring socio-economical, as well as, environmental benefits to the population. This was done by applying tools designed to analyse and resolve conflicts, specifically the Graph Model for Conflict Resolution (GMCR).

This article is structured in four sections: section two presents the theoretical foundation of the tool applied. Thirdly, the application of this method, and finally, the conclusion with the results and remarks.

2. The Graph Model for Conflict Resolution (GMCR)

Disputes emerge naturally from human interaction, conflicting interests usually are complicated to deal with and end up halting progress, so they must be solved. With this in mind, many methods, frameworks and technologies have been applied in the analysis and resolution of conflicts, throughout history, in hopes of getting better outcomes out of it.

Following this line of thought, the graph model for conflict resolution (GMCR) was developed in an attempt to aid practitioners in solving conflicts. Firstly proposed by Kilgour [1987] and improved over the years by many authors, it is a mathematical model also based on concepts of metagame analysis, conflict analysis and game theory.

According to Xu et *al.* [2018], the GMCR is a methodology for analyzing strategic conflicts with solid mathematical foundations. Additionally, it effectively examines decision-makers' (DMs) behavior, once it takes the form of states instead of individual decision when describing the conflict. Also, as it does not require complete knowledge of the DM's preferences, it is an easy to use method to help provide valuable information to support the decision-making process, as well as, structural insights, and answers to what-if questions.

Moreover, the mechanism englobes disputes in which the actors may have different options or actions under their control, separated value systems, objectives, or preferences. This also makes it do well in modeling strategic moves and countermoves among the decision-makers. For all that is said before, it is clear that the tool can unquestionably be used to extensively analyze the possible strategic interactions between key players in order to ascertain possible resolutions or equilibria of a conflict.

The GMCR usage consists of two main phases: modeling and analysis. In the modeling phase, various problem structuring methods (PSM) can be applied to allow multiple perspectives of the problem to be reviewed. The aim here is not to solve the conflict per se, but to understand it objectively. Typically, these models use a qualitative approach (words, pictures and/or numbers) to represent the understanding of the problem by the decision-makers [Midgley 2017].

For the analysis phase, the tool consists of a directed graph and a payoff function for each decision-maker who can influence the conflict. Depending on a preference relation over U

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for each DM, numerous graphs Di = (Ui, Ai), i ∈ N, can be used to model the direction of the dispute, where:

- N = {1, 2, .., n}. denotes the set of decision-makers; and
- U = {1, 2, …, u} the set of possible states of the dispute.

After structuring the problem, possibly with the help of a PSM, the GMCR uses it to model a dispute from the point of view of transforming states (the vertices of a graph) via transitions (the arcs) controlled by the main actors. As it is true for other tools, it is assumed that the DMs are able to express their preferences by a binary relation on U. Furthermore, due to the nature of its conception, this apparatus has some innate properties it can incorporate to help design and solve practical real-world problems: irreversible moves, common moves, forcing moves and path-dependent transitions [Hipel et al. 2012].

The next phase is comprehended by the stability analysis where the solution concepts or equilibrium criteria are evaluated. Hipel et al. [2020], present seven solution concepts that have been refined to be used within the GMCR, Table 1. These concepts try to capture the behavior and dynamic interaction each decision-maker might show in a conflict, taking into consideration the foresight of possible outcomes of their movements and their willingness to move to a worse state (disimprovement) deliberately. When all DMs share a particular stability criterium (solution concept) at some point, this state becomes a possible conflict resolution (equilibrium).

Table 1- Possible solution concepts for GMCR

Stability Criteria	Definition	Foresight	Disimprovement
Nash stability (R)	DM cannot unilaterally move to a more preferred state. He or she does not analyze possible opponents' reactions to their movements.	Low	Never
General Metarationality (GMR)	All DM's unilateral improvements are sanctioned by subsequent unilateral moves by others. Furthermore, they are only aware of their own preferences. This is a conservative (risk aversion) strategy.	Medium	By opponents
Symmetric Metarationality (SMR)	All DMs, in addition to considering their own possibilities of movement and reactions of other players, also consider their chances of counter-reaction, anticipating how the conflict will end after this. This is also a conservative strategy.	Medium	By opponents
Sequential Stability (SEQ)	Any DM's unilateral improvements (UI) are sanctioned by others' subsequent UI. That is, the player considers his and the opponents' possible movements, and anticipates that a sequence of unilateral improvements of the other players will result in a less preferred state for him than his initial state. With this strategy, the focal DM may choose to take some risks.	Medium	Never

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Symmetric Sequential Stability (SSEQ)	The DM who makes his or her UI first considers not only the reaction of the opponents but also his own counterreaction.	Medium	Never
Limited Move Stability (Lh)	All DMs are assumed to act optimally given a specified maximum number of state transitions (h). Consecutive movements by any DM are not allowed. In this scenario, one might accept the risk and strategize his or her actions.	Variable	Strategic
Non-myopic Stability (NM)	Corresponds to the limit of Limited Move Stability (Lh) when the maximum number of state transitions (h) tends to infinite	High	Strategic

No direct application of the GMCR to resolve a conflict between the regulatory agency and users/producers of photovoltaic energy has been found by the authors in the literature. As an example of usage of this tool, in a somewhat relatable context, can be seen in Xu et al. [2019], where the authors apply the evolutionary game theory and GMCR to try and achieve a win-win-win situation, for the government, enterprise and household, in the challenges that have impeded the development of China's Photovoltaic Poverty Reduction Program.

Another example is presented by Ali et al. [2019], in their paper, they discuss an adaptation of the GMCR to solve energy-environmental conflicts that may emerge due to evolutional changes in decision-makers' available options and preferences. Differently, Aires et al. [2019] use the graph model on the conflict between the Union bodies, the managing States and water users in the Piranhas-Açu River watershed to study water usage after the expiration of a previous regulatory framework, which determined the rules for exploring the resource. Still under Brazilian regulatory context, Araujo and Leoneti [2020] make use of a game theory approach enriched by equilibrium solution concepts present in the GMCR to evaluate the stability of the oil and gas exploration and production regulatory framework in Brazil, reinforcing that the use of this methodology can be of great validity to understand and quantify the preferences of the players and foresee possible outcomes of conflicts of this type.

The utilization of the Graph Model for Conflict Resolution (GMCR) is best done with the aid of a decision support system (DSS), which is commonly composed of three main parts plus a user interface, Figure 1. One can notice the interaction, may it be by an analyst or one of the conflict actors, via the user interface, with the modeling subsystem, analysis engine and output interpretation subsystem when going into a dispute.

The first step takes place within the modeling subsystem, where a conflict model is developed in terms of DMs, options, feasible states and preferences. After determining the initial conflict model, the user moves to the analysis engine where he or she can instruct the machine to carry out a stability analysis and thereby establish the possible resolutions to the conflict. Finally, the user is able to check the output interpretation subsystem where it is possible to find many different types of reporting options that may help the actors in gaining new insights and a better understanding of the dispute under study.

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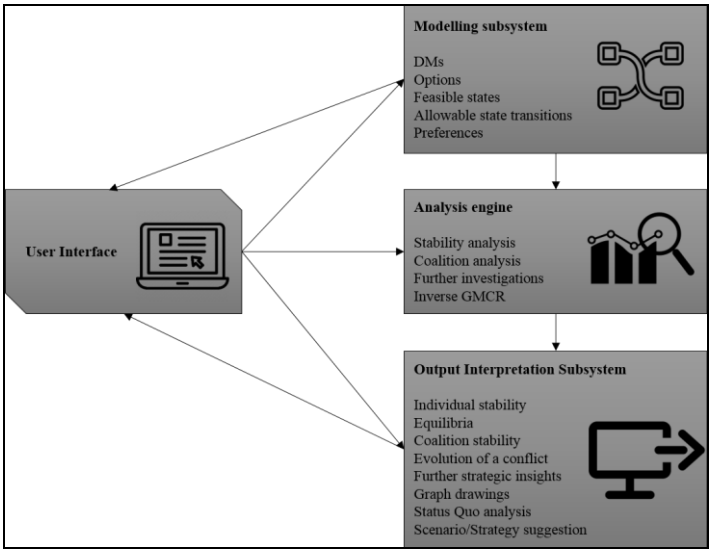

Figure 1- Basic design of DSS for the GMCR.

3. Resolving the conflict

According to Vianna [2013], this research can be classified as of applied nature with an exploratory bias, because it has an immediate purpose of solving a real world problem. Furthermore, Sá-Silva et al. [2009] explain that the procedure of data gathering used can be labeled as "documental research" because the data has not been analytically treated yet, as is mostly the case within this study in which the vast majority of input information comes from official news portals, publications, archival data, media (presentations, interviews, etc.), and from scientific journals; the date range contemplated is up to ten years.

3.1. Background of the conflict

As mentioned in sec 1, the present moment in Brazilian history presents a dispute between its national agency of electric energy (ANEEL) and owners of solar distributed generation (SDG) technology. After many years of providing subsidies on tax and other forms of support for the development of the photovoltaic energy sector, there is now a movement towards the removal of this help. This move has been called because two main issues arise: (i) loss of money and (ii) unfair advantages.

On one hand, there is ANEEL, it is an autarchy under special regime linked to the Ministry of Mines and Energy (MME) and created with the purpose of regulating and supervising the production, transmission, distribution and commercialization of electric energy. Its role is to act on behalf of the population as a whole; thus, providing fairness and equity on the regulatory framework of SDG. This actor has an important position in the conflict because it has the power of changing the *status quo.* On the other hand, there are enterprises, business and households that invested in SDG. This group has spent money buying photovoltaic technology (PV) aiming to get not only financial advantages, but, also, to collaborate with a healthier and more sustainable environment.

The main problem identified is that owners of PV technology are getting unfair advantages because they use the electric grid the same way not-owners do but are not paying for its costs. The net-metering system, in the way it is operating now, allows for almost complete avoidance of infrastructure costs related to the distribution of electric energy which, in turn, makes common captive consumers (not owners of SDG) bills' rise. In contrast, the part of the population that has already invested in this technology fear to have a financial loss and say that

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the subsidies are necessary to foster the development of this energy source until it reaches a stable level. Moreover, some imply that the subsidies are still not enough because most of the equipment comes from abroad and, therefore, import taxes apply [Senado Federal 2019].

For this reason, ANEEL has to suitably balance the policies to encourage development while not furthering social and economical gaps. With that in mind and in the hope of solving this problem, the present conflict was modeled and analyzed with the assist of a decision support system tailored specifically for the graph model for conflict resolution called GMCR + software.

3.2. Modeling

There are two main DMs in the Brazilian solar distributed generation regulatory conflict, the regulatory agency (DM1) and the group composed of captive consumers that produce part of their electric energy through photovoltaic technology (DM2), as seen in the left-hand column of Table 2. Other players of the electric sector like the national congress, the Ministry of Mines and Energy (MME), the National Energy Policy Council (CNPE), the National Electric System Operator (ONS) or the Electricity Trading Chamber (CCEE) are not modeled as DMs since they do not strictly control any option that would exert direct influence on the conflict. Even though some might have influence over ANEEL, the national electric agency has operating autonomy and is responsible for defining the regulatory framework of electric energy.

For this conflict, the DM1 controls three options. One, theoretically, on its favor (O1), one disfavorable (O2) and a neutral (O3): (O1) reduce the ongoing incentives and subsidies ("Decrease incentives"), (O2) increase incentives and subsidies to investors in PV technology ("Increase incentives") and (O3) to leave things as they are ("Take no action"). In contrast, the DM2 has the options of (O4) agreeing to the decisions made by the regulatory agency ("Agree to new decisions") and (O5) to hit back ("Retaliate"), trying to force new decisions to be made, by going on riot, protesting, lobbying, though a petition, etc.

Table 2 - DMs, options and feasible states for the Brazillian SDG regulatory conflict.

DMs and options	Feasible States				
	1	2	3	4	5
Regulatory agency (DM1)					
Decrease incentives (O1)	Y	N	N	Y	N
Increase incentives (O2)	N	Y	N	N	N
Take no action (O3)	N	N	Y	N	Y
Users/producers (DM2)					
Agree to new decisions (4)	Y	Y	Y	N	N
Retaliate (O5)	N	N	N	Y	Y

3.3. Infeasible states and Irreversible moves

Originally, there were a total of 32 (a combination of the 5 options available - 2^5) possible states; however, 27 states are deemed infeasible, that is, the options chosen by, at least, one of the DMs cannot occur concurrently. For example, DM1 cannot opt to increase and decrease the incentives at the same time. Likewise, it is not rational to consider a state where the DM2 would agree to the new decisions and retaliate at the same time or that it would not agree with and still not retaliate, as this could be seen as if it had agreed in the first place. Table 2 shows 5 columns representing the total number of feasible states, with 'Y' indicating when the relative DM chooses to take that option, and 'N' indicating it was not selected.

It is important to notice that a DM can move unilaterally, back and forth, between feasible states by modifying its option choice, excluding the case in which the option is

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irreversible. In the present conflict, option O5 (“Retaliate”), for the DM2, is deemed irreversible as it would probably take the form of a riot, protest, media exposure, etc.

3.4. Preferences

There are many different ways to rank the preferences for a DM, one can use any formal methods present in the literature of Multi-attribute value theory (MAVT) or Multi-attribute utility theory (MAUT) like SWING and trade-off. On the other hand, an easier and more intuitive approach may be taken, like directly ranking the states or specifying its preferred conditions. In this study, the direct ranking of the states, from most preferred to least, was estimated for each DM, by the authors, after evaluating their interests and attributes. On the right-hand side of Table 3, there can be seen the ranking (from most preferred on the top to least preferred at the bottom) of the preference statements. It can be noticed that, for DM1, preference statements 4 and 5 have the same weighting and for DM2 the statements number 1 and 5 have the same value as least desirable.

3.5. Equilibria results and insights

The equilibria results screen in Figure 2 shows that states 4 and 5 fulfill all the stability criteria; thus, they are the strongest equilibria for this conflict. State 3 comes afterward because it does not present Nash nor simultaneous stability (SIM). Also, states 1 and 2 are the weakest equilibria for this conflict since they are stable only for two stability definitions: GMR and SMR. This is reasonable since these states are the most desired (most conflicting) by DM1 and DM2, respectively, but can be sanctioned by unilateral improvements of the opponent. Furthermore, if both DMs were to manifest a coalition behavior every state would show strong equilibria.

At this point, these findings suggest that the resolution to this conflict is likely to be the regulatory agency making no move or decreasing the incentives and expecting the group of “prosumers” to react to this decision with a retaliation (states 4 and 5), which is something not desirable for both DMs.

Table 3 - Preference statements for DM1 and DM2

n°	**Preference statements**	**DM1**	**DM2**
1	DM1 decreases incentives, while DM2 agrees to the decision.	1	2
2	DM1 increases incentives, while DM2 agrees to the decision.	3	3
3	DM1 takes no action, while DM2 agrees to the decision.	2	4
4	DM1 takes no action, while DM2 retaliates.	4,5	1,5
5	DM1 decreases incentives, while DM2 retaliates		

The goal of an intervention or an analysis of a conflict is to produce a better resolution for all parties. In this case, a preferable solution would involve the willingness of DM2 to agree with the action DM1 proposes, as is the case in states 1, 2 and 3. Taking into consideration that state number 3 is the *status quo* of the conflict, in order to determine a more desirable solution and explain how it could be achieved, the tool “inverse GMCR” was run for states 1 and 2 [Kinsara et al. 2015].

Being Nash and SEQ the strongest stability definitions (rational DMs would not want to move from a particular state after attaining it) the goal was set to reach equilibria on those concepts. With that in mind, the inverse calculations were run and returned 224 possible permutations for state 1 and 456 for state 2 resulting in the patterns depicted in Table 4 and Table 5. From that, one can see that state 1 will be the resolution to the conflict if the users/producers

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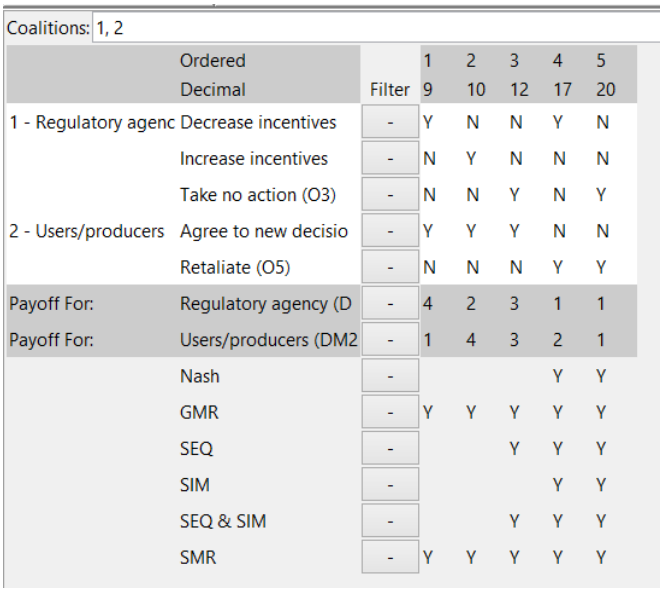
prefer not to retaliate even if ANEEL opts to decrease the incentives. Whilst for state 2 to become the resolution of the conflict, ANEEL must consider that it should increase the incentives.



Coalitions: 1, 2

	Ordered		1	2	3	4	5
	Decimal	Filter	9	10	12	17	20
1 - Regulatory agenc	Decrease incentives	-	Y	N	N	Y	N
	Increase incentives	-	N	Y	N	N	N
	Take no action (O3)	-	N	N	Y	N	Y
2 - Users/producers	Agree to new decisio	-	Y	Y	Y	N	N
	Retaliate (O5)	-	N	N	N	Y	Y
Payoff For:	Regulatory agency (D	-	4	2	3	1	1
Payoff For:	Users/producers (DM2	-	1	4	3	2	1
	Nash	-				Y	Y
	GMR	-	Y	Y	Y	Y	Y
	SEQ	-			Y	Y	Y
	SIM	-				Y	Y
	SEQ & SIM	-			Y	Y	Y
	SMR	-	Y	Y	Y	Y	Y

Figure 2 - Equilibria results screen from GMCR+

Table 4 – Preference profiles needed to achieve state 1 as resolution to the conflict.

State 1	DM1	DM2
Nash	1 must be more preferred than 2 and 3	1 must be more preferred than 4
SEQ	1 must be more preferred than 2 and 3 or if 5 is more preferred than 3 for DM2, 1 must be more preferred than 5 for DM1	1 must be more preferred than 4 or 5 must be preferred to 4 by DM1 and 1 must be preferred to 5 by DM2

Table 5 - Preference profiles needed to achieve state 2 as resolution to the conflict.

State 2	DM1	DM2
Nash	2 must be more preferred than 1 and 3	Always stable as there are no moves from 2
SEQ	2 must be less preferred than 1 and 3 **OR** if 4 is preferred to 1 for DM2, 4 must be less preferred than 2 for DM1 **OR** if 5 is preferred to 3 for DM2, 5 must be less preferred than 2 for DM1	Always stable as there are no moves from 2

4. Conclusions

This paper analyzed an ongoing conflict on the Brazilian regulatory framework of solar distributed generation (SDG) by using the graph model for conflict resolution approach. The dispute involves the possible end of incentives for the development of this type of technology, by the Brazilian regulatory agency (ANEEL), and the downsides it would cause to the ones that already invested in it.

In order to analyze and solve this conflict and, therefore, to set the most appropriate course of action for the solar distributed generation regulatory framework, taking into account economic, environmental and social aspects, the software GMCR+ was applied. The first analysis (standard GMCR) focused on determining the equilibrium states, that is, the states that no DM has any unilateral improvement they can perform. Therefore, these equilibrium states more than often mean the end of the conflict. It showed the most likely outcome will be the regulatory agency leaving things as they are today or decreasing the subsidies which would, in turn, make the group of "prosumers" retaliate as a form of influencing the agency to re-evaluate and possibly achieve a better outcome for them.

However, this classic methodology does not do well in determining a more desired resolution nor explains how to achieve it. To fulfill this gap, the inverse GMCR tool was applied and new insights into the conflict were discovered. It displayed the need for a cooperative behavior when determining which moves to make as the preferences of each DM are very conflicting but some desires are shared, ANEEL doesn't want to cope with a retaliation neither the users/consumers wishes to have to fight. Therefore, it is clear that a third-party, in the role of a mediator, could be advantageous and help achieving trade-offs that would result in a state jump from what is likely to be the resolution to the conflict to a more desirable one or the creation of better states.

All in all, the goal of analyzing and uncovering possible course of actions to this conflict are considered to have been reached. Furthermore, the study demonstrated the applicability of the DSS GMCR+ in the analysis of a real-world conflict and its usefulness as a strategic tool that can aid in the decision-making process and, even, can be used as a negotiation tool. As for recommendations to future works, it is suggested to have a closer involvement with the key actors or to use expert knowledge when determining the preferences of the DMs, so as to bring a more accurate model and yield, possible, better results.

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