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On framework development for the dynamic prosumer coalition in a smart grid and its evaluation by analytic tools

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Abstract

Managing prosumers participation in energy trading becomes complicated, as the number of prosumers in smart grid is expected to rise. In this situation, it is safe to group active prosumers into groups or coalitions. By utilising analytical tools, like game theory, the method for grouping or coalition formation of prosumers can be carefully studied. After analysing prosumers behaviour in energy profile, we propose a novel dynamic, decentralised prosumer coalition formation method based on game theory that can satisfy utility grid demands. A conceptual framework is developed for coalition formation and energy management among prosumers in a dynamic environment. This approach has the potential to increase the size and number of coalitions without a central controller to better manage renewable energy usage and trading with energy buyers. We validate the performance of adopting a game theoretic approach, assessing the strategy using open and shared data sources.

Keywords: Smart grid; Prosumer; Coalition; Game theory

1. Introduction

Smart grid has been an accepted energy technology for the next generation of the power grid. We are able to modernise the notion of the traditional power grid by utilising advanced information from communication, control technology and innovative analytical techniques. The research aims to develop a framework and form prosumer coalitions that can meet utility grid requirements and grow with active prosumers to better manage renewable energy usage and distribution. The other associated objectives are:

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- Analyse prosumers behaviour based on their energy profile.
- Develop a method to rank prosumers based on their energy profile behaviour.
- Design a dynamic, decentralised coalition formation technique to group prosumers to better manage renewable energy usage and trade in the power market.
- Develop a decentralised energy trading method, based on game theory to trade the maximum surplus energy that each coalition is ready to promote and sell.
- Optimise the prosumer coalition function that benefits both prosumers and power markets.
- Develop a fair pricing method for the supplied energy based on the type of demand.

The literature review about prosumer coalition formation, energy trading and fair pricing based on the prosumer's energy profile are discussed in Section 2. Section 3 highlights the research issues and challenges that motivated us to develop a framework for prosumer management. The significance of the proposed research is explained in Section 4. The methodology of implementing coalition formation is given in Section 5. Section 6 describes the methods for evaluation and implementation of the framework. Conclusions are drawn at the end of the paper.

2. Literature Review

Over the last hundreds of years, electricity was widely distributed unidirectional with the help of power transmission cables and transformers that are not so economical in today's generation. The power loss and a few other safety hazards that come with these cables have forced the government to bring about a change in these policies which affect the power companies. Since we live in a fast-paced economy with rapid improvements in every sector, the consumer seeks a more reliable, manageable and cost-effective power system [1]. Technological advancement in communication systems has changed the way we look at electrical networks. The idea of a "prosumer" where the power user not only uses power but also produce power and share it with other energy users have come into play [2]. This grid can be designed using new techniques to optimise consumption as well as the distribution of power sources.

With increasing in energy demand and available limited power resources, a need arises to develop a smart energy management system that involves a complex and active power grid composed of power companies and green sources, traditional power sources and loads, as well as new customer-owned devices such as storage units or electric vehicles [3]. Modelling, analysing, and better studying energy management in such a heterogeneous dynamic environment is a significant step in the smart grid deployment. Another important task within this heterogeneous environment is the effective design and evaluation of power transaction methods among substations, utility grid, renewable energy sources, electric cars, and energy users. Traditionally, a restricted range of participants was involved in power transactions, and they were ruled by a hierarchical, centralised power market. In contrast, with the contribution of green energy sources and prosumer's increased capacity to control the renewable energy usage provides new openings for energy transactions (trading) in the retail power market. As a result, prosumers can efficiently solve problems related to what or where or when to trade energy [5]. Even though it results in a distributed, localised energy trading markets in the smart grid, their associations with the utility grid and energy management turn out to be complicated. So, it has to be carefully examined by analytical approaches such as game theory.

Game theory is a formal analytical and conceptual set of mathematical techniques that can help in understanding complicated associations between independent and interdependent players and also helps in making independent and interdependent decision making concerned with different problems. Thus the game theory can help in making logical and fair decisions about energy trading and management among the various players (substations, utility grid, renewable energy sources, electric cars, and prosumers and energy users) in the smart grid. There is a need to develop new energy management mechanisms based on game-theoretic concepts that can capture realistic energy behaviours of prosumers. This approach motivated to group prosumers by optimising the associated benefits and costs among different players during energy transactions. In this research, we propose a novel framework that can integrate prosumers (based on their realistic energy behaviour) to form prosumer coalitions that can fulfil utility grid requirement, and also can better manage the renewable energy usage and distribution. We will also develop a fair pricing method for the supplied energy based on the type of demand.

2.1 Analyse prosumers behaviour based on their energy profile

In this section, we shall discuss the existing literature that analyses the behaviour of prosumers and highlights the associated shortcomings.

Research on prosumer behaviour analysis causes tremendous change both in the proper behaviours and in the factors that impact prosumers [7]. To regulate this variation, the authors in [11], classified prosumers' behaviour among the three domains. Firstly, the personal domain which includes each prosumers' core ethics, views, motivations, or their emotional state. Secondly, the behavioural domain which includes the factors that take their commitment level to keep renewable energy resource, and their flexibility to change their energy consumption. Finally, the contextual domain which includes prosumer's background details such as social, financial, educational, etc., and their possessions, financial situation, public context such as rules and regulations, and their ecological conditions such as climate. In the research performed by [10], a framework has been proposed which explained the purchasing power commendations to classify consumers regarding their features. Prosumer's behaviour analysis on energy profile is further investigated in the European project AIM [11] that examined the energy profile in two different approaches- offline mode (includes resident presence profile, temperature details and lighting details and other factors in predicting upcoming behaviours and decision making) and real-time mode (includes data that could be used for handling unexpected modifications in energy management systems). Also, some researchers have performed prosumer behaviour analysis based on their energy demand and supply. Those researchers have shown that the prosumers' energy consumption and production features have a direct influence on their energy sharing behaviour.

In accordance with the demand and supply mechanisms, numerous investigations [15] have been performed. Most of them have the fundamental concept of balancing demand and supply by assigning total power demanded equal to the total supplied power. Going a step further, the literature [5] analysed the prosumer behaviour on the smart grid and had shown that the economic incentives given to prosumers are necessary for encouraging either grid-friendly or grid-unfriendly prosumer behaviour. The prosumer's motivational scheme to assess their favourable or unfavourable behaviour on distributed grid operation and grid planning decisions are heavily overlooked in this literature and have not comprehensively addressed their behaviour on the energy profile. Even though there are numerous existing methods of power consumption analysis [17], but only little consideration has been devoted to green energy production and sharing by prosumers.

In contrast, some energy trading methods have been described in [17] based on prosumer's energy sharing behaviours and developments in smart grid technologies as well as opportunities in the energy transaction. Even though the researchers have explained the energy generation and energy sharing profiles, but they have taken a more traditional centralised approach. It has been shown in the existing literature that it is better to understand prosumer's behaviour, both in generation and consumption and also in sharing to provide better energy services. However, in all these proposals mentioned above, the influence of power generation behaviour of prosumers using game theory is not addressed.

2.1.1 Critical analysis of existing prosumer behaviour analysis methods

Studying various methods for prosumer behaviour analysis on the energy profile reveal that most of them focus only on the influential factors for studying the behaviours of prosumers. On the other hand, some have focused on understanding household energy consumption and energy sharing behaviour in a traditional structure. However, no work has been able to analyse the prosumer behaviour on energy profiles that enable to produce and share more renewable energy and can trade power efficiently based on the decentralised game theoretic approach.

2.2 Prosumer coalition definition and formation

From the analysis of prosumer energy behaviour, suitable prosumers can be discovered to form groups (coalitions) of similar energy behaviour for trading energy with energy buyers. In the context of this research, coalition formation model would be defined based on the prosumer energy behaviour, utility grid requirements and some further parameters that would be known only after further study of this topic. The defined coalition function should satisfy the grid requirements such as minimum production requirement and maximum stability. This section analyses the existing schemes that form prosumer groups or clusters to trade energy between the groups and the energy buyers.

Most of the research proposals [4, 18] consider only a single energy user (prosumer/consumer) connections with power market contributors. There are some other research works [19, 20] that addressed grouping energy users and have not discussed the idea of prosumers. Some research works grouped prosumers for energy exchange using agent-oriented methods and graph tools. On the other hand, several research works cluster prosumers using game theoretic approach to form coalitions. Coalitions can be formed either as static or dynamic [21]. Static coalition formation methods cannot join a new member to a coalition or cannot delete an existing member from a coalition. Instead, dynamic algorithms can make alterations in the number of members in coalitions when a new member comes, or an existing member leaves. For example, a dynamic coalition formation is proposed based on agent-based functions [22] to integrate and arbitrate the benefits and negatives among the participants in energy trading. Coalitions are formed among players based on balancing supply and demand, backup storage and physical network limitations.

In the same way, [20] proposed a cooperative game-theoretic approach to form communities with mutual decisions among customers to minimise the peak energy demand by scheduling the appliances in a collaborative manner, which alleviates customers energy consumption cost. Alternatively, there are research proposals [30] on dynamic coalition formation among energy users and grid and not between prosumers and grid. For example, [23] proposed a dynamic coalition formation method for efficient energy utilisation among micro-grid and customers. We can see from the state of the art mentioned above that the game theory can give resolutions for many related issues in the smart grid but also confronts many design challenges. In any case, we also noted that many of these proposals are based on the traditional static non-cooperative game theory. Thus, it is significant to develop dynamic game models in a real-time environment that depend on time-varying parameters.

The prosumer management concepts are not addressed in the above literature, but they explained the formation of a coalition among energy users. Alternatively, a Prosumer-based Energy Sharing and Management (PESM) scheme [21] was developed to manage individual prosumers who have the excessive energy to sell to those who need energy. A centralised network restricts coalitional game model [26] was proposed to manage energy consumers by forming coalitions through social network contacts to buy electricity together. However, they formed effective coalitions and allocated payments to individual members using linear programming techniques, but were managed by a central controller. In contrast, to centralise coalition formation algorithms, the authors in [27] have proposed a decentralised coalition formation method without a central controller. A multi-agent decentralised coalition formation model [26] was proposed based on a negotiation protocol to trade energy in power distribution networks. To manage the different players in the smart grid by preserving their privacy, a decentralised dynamic coalitional game model based on a distributed online protocol is proposed in [28]. Even though monetary incentives are offered, prosumers were not ready to change their loads to a different time, but have considered reducing their total consumption (based on the assumption that a certain income could be achieved). In all these methods, the energy requirement value is fixed once a load is created. Hence, it shows that these methods will not work in a dynamic environment where energy requirements' values vary dynamically. Furthermore, a decentralised stable coalition formation method [19] was developed for energy users using social networking but failed to address the concept of the prosumer. Also, the static distribution network was used in where new energy users cannot join, and existing energy users cannot leave.

2.2.1 Critical analysis of existing prosumer grouping methods

Reviewing of the above-mentioned methods reveals that most of the existing methods focus on grouping energy users (consumers/prosumers) in a static environment with a central controller to coordinate energy trading. However, no work has been able to develop a framework of decentralised coalition formation in a dynamic environment to improve economic and technical aspects by considering time-varying parameters in power generation and demand.

2.3 Prosumer coalitions energy trading

The notion of prosumer coalitions energy trading based on game theory involves three players- electricity consumers (energy users who are not involved in any renewable energy consumption), prosumers (energy users are involved in renewable energy consumption and production) and power utility grid (a seller with infinite capacity). Even though prosumers can produce and consume energy directly, but can sell its excess energy at a flexible rate to any energy buyer on the power network. Thus prosumers act as an energy seller (if their energy production goes beyond their consumption) and energy buyer (if their energy production does not meet their energy demands) [29]. This section analyses the existing schemes that trade energy between the prosumer coalitions and the energy buyers.

The research was done by Capodieci, and Paganin [4] offer an energy trading model where individual prosumers can trade energy with power companies and energy buyers based on an agent-oriented technique to attain their autonomous objectives. Lamparter et al. [26] developed an agent-driven method, in which energy trading is based on a local policy concerned bidding strategy, where the agent can control user restrictions or preferences. Similarly, a framework for energy trading in a decentralised distribution network is proposed in with the objective of energy consumption reduction at peak hours using serious game design. Though there are many other research proposals for active trading between consumers and power companies, none are based on energy trading among prosumer coalitions and energy buyers based on game theory.

2.3.1. Critical analysis of existing prosumer energy trading methods

The significant drawback in most of the above research proposals is that they are based on the interactions of single energy user with power trading contributors. Also, some of them focus on integrating the interdisciplinary characteristics of power systems, networking, communications for energy trading while others focussed on the demand side and an optimisation problem for the grid. Overall, no aforesaid research efforts have been able to develop a decentralised game model among prosumers and energy buyers which can strategically trade the maximum amount of energy surplus by incorporating the requirements of the utility grid, the demand side needs and the optimisation problems that capture the benefits to both players involved in the trading.

2.4 Prosumer fair pricing method

Different types of pricing schemes are used in the smart grid that ranges from time-of-electricity-usage to real-time power billing. Different terms are often used to report them for example, Variable Peak Pricing, Critical peak pricing, Time-of-use pricing, Critical Peak rebates, Real-time pricing. In all these pricing schemes, except for Time-of-use pricing (TOU), are dynamic pricing methods because the price changes over the hours on different days. Even though in most proposal reports in the literature, prices or rates and tariff are referred similarly, but there are differences between them. A tariff is an officially accepted charge that power companies offer to customers based on their electricity usage which is noted in their meters and is well-specified and consistent for a certain period [31]. A TOU based model on fixed price elasticity was proposed to minimise the total generation cost [32]. Alternatively, a TOU pricing method based on variable price elasticity was developed to reach stability in profits of electricity companies to reduce the electricity bills of consumers [32]. Considering the different sources of uncertainties related to price elasticities of demand, another TOU tariff model proposed in [33] minimises the total generation cost. Similarly, an optimal decision model proposed in [34], step tariffs based on price elasticity matrix and reduction of power consumption are highlights. On the other hand, based on load management, different compensation rates are studied for encouraging more customers to sign up for the interruptible load contracts. However, they failed to consider the power system dispatch in a market environment. Based on market clearance and bids, another tariff scheme was proposed in [34] discusses the bidding strategies of interruptible loads participating in market operations. A coupon pricing scheme was proposed [35] to minimise the overall generation cost and maximise the profits of retail companies and consumers. The pricing schemes suggest a smoothening structure in their power consumption behaviour while implementing their pricing methods. However, it shows a method which can affect peak shifting when customers rationally react to price signals if definite approaches of limited rationality are not assigned.

2.4.1 Critical analysis of existing prosumer fair billing methods

When analysing the impacts of different pricing schemes on retailers and consumers in power market, most of them have not taken into account of the uncertainty in consumer's behaviour and hence could not conduct a quantitative analysis of the differentiated consumption behaviour. Because of this, their models cannot show how different categories of consumers respond to the same pricing scheme. In other words, because of the limited information to manage large-scale geographically dispersed prosumers, most of the pricing models cannot define differentiated tariffs, which are essential for encouraging different classes of consumers to participate in the cheapest price plan. However, the pricing models mentioned above were based on the assumption that system operators have extensive information of consumers and the information is accurate.

3. Issues and Challenges

After performing a thorough review of the literature, there is a need to set up a method for forming a prosumer coalition for effective energy management among different players of a heterogeneous smart grid environment. The following research issues have been identified in developing a framework for prosumer management:

1. Analyse energy behaviours of prosumers to find out suitable prosumers to form coalitions.
2. Rank prosumers based on their energy behaviour.
3. Group active prosumers together into groups as the number of prosumers are expected to increase.
4. Introduce trust and reputation parameters to encourage prosumers to participate in the coalition.
5. Develop an efficient strategy that can connect prosumer coalitions in conformity with the utility grid, instead of single prosumers.
6. Meet the utility grid demands regarding stability and minimum production.
7. Have an efficient energy trading method between prosumer coalitions and energy buyers.
8. Have fair pricing for the traded energy based on the type of demand.

In a dynamic heterogeneous environment in a smart grid, game theory can provide a strong framework that can address all the above-mentioned research issues.

4. Significance, Motivation and Contribution

In this section, the importance of the research is explained in two sub-headings: socio-economic significance and scientific significance.

Socio-Economic Significance

1. Improves the energy supply regarding quantity and quality over the long run
2. Enhances the prosumer's participation in energy transactions over a period of time
3. Increases prosumer's determination to participate in energy trading
4. Support the consumption and production of renewable energy (green-energy) hence minimising the ecological impact
5. Decreases the energy trading cost and energy loss
6. Achieves sustainable energy trading

Scientific Significance

1. The research offers a novel coalition-based approach to manage prosumers in smart grid energy trading.
2. An advanced framework is developed using game theory for prosumer coalition formation.
3. We propose a novel technique for making prosumer coalitions in a dynamic environment using game theory.
4. We suggest an optimisation function that can capture the benefits and associated costs in energy trading.
5. We introduce a fair pricing method based on the type of demand using a game theoretic algorithm.

5. Methodology

As pointed out earlier, the objective of the research is to implement a new model and methods that result in a theoretical framework for coalition formation and energy management in a smart grid. To achieve the research aims, we propose new algorithms and prototypes in accordance with the 'making something work' approach. The different research stages that we plan to implement are broadly categorised into three levels as follows:

Conceptual Level: We plan to build new constructs based on the proposed approach by examining the existing literature and identifying issues. A detailed review of related literature is done based on the prosumer behaviour analysis, prosumer clustering methods, prosumers energy management in energy trading process and different pricing methods in the smart grid to identify their limitations. Also, a further study is carried out to ascertain the extent to which these can be used to develop new algorithms for smart grid prosumer coalitions. In the research, additionally, we review the literature on energy trading and pricing to identify the parameters energy users used in green energy consumption and production. This stage comes under the conceptual phase of science and engineering-based approach.

Perceptual Level: We envision a new model by new technology articulations and re-engineering tools to develop a conceptual framework for coalition formation and energy management among prosumers. In this stage, we develop a novel framework for forming coalitions and managing energy among prosumers in a dynamic environment. The proposed coalition model can have two main processes namely prosumer coalition formation and overall prosumer coalition energy management. The second stage comes under the perceptual phase of the science and engineering-based approach.

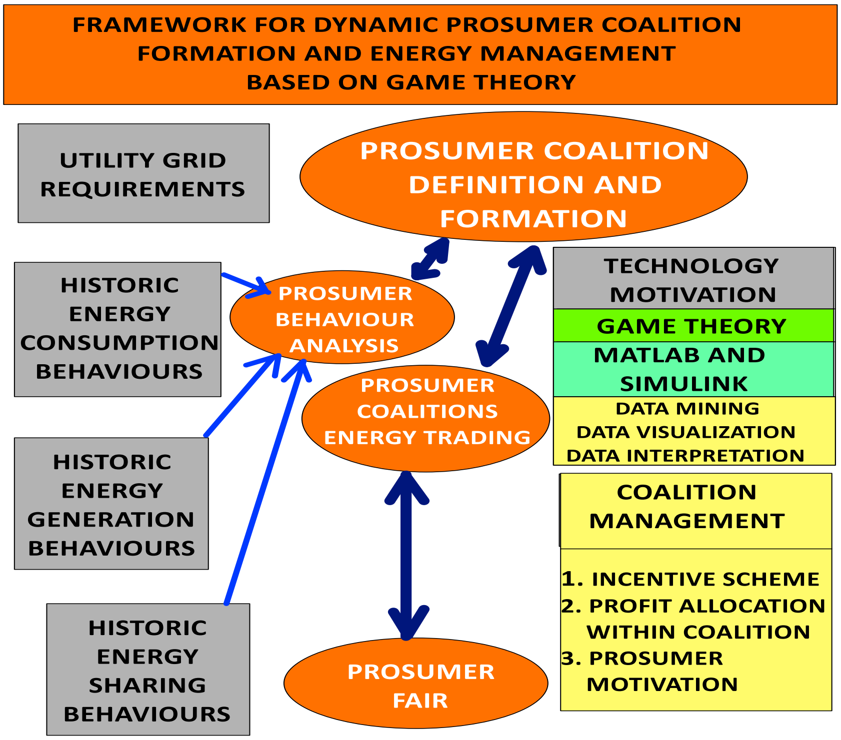

Figure 1. Framework for dynamic prosumer coalition formation and energy management

As shown in Fig.1, the model for prosumer coalition formation and prosumer energy management based on game theory are carried out in different phases, as described in the following sections:

Phase 5.1: Prosumer behaviour analysis

Each prosumer's unique energy profile includes various parameters based on energy consumption, production and trading. Firstly, a technique is being developed to analyse each prosumer's behaviour based on the different energy attributes in their energy profile. After the prosumer's behaviour analysis, we shall categorise and rank them based on their energy profile behaviour. For implementing this step, we generate an energy profile using a Matlab tool and access the publically available data.

Phase 5.2: Prosumer coalition definition and formation

In this step, a decentralised coalition formation model would be defined among prosumers and energy buyers, without a central controller by allocating the decision-making process to prosumers themselves. The model will be based on the prosumer behaviour analysis performed in phase 1, utility grid requirements and some other parameters that would be known only after further study of existing related works. The defined coalition function can satisfy the grid requirements such as minimum production requirement and maximum stability. Also, we implement the proposed model in a dynamic environment where the number of members in the coalitions can vary when a new prosumer joins or an existing member leaves from the coalition. The time-sensitive factors in power generation and demand are considered in the proposed method.

Phase 5.3: Prosumer coalitions energy trading

In this step, a decentralised energy trading game model is developed which can strategically trade the maximum amount of surplus energy by integrating the requirements of the utility grid, the demand side needs. Also, we will optimise the coalition function that can capture the benefits of those involved in energy trading as well as the associated costs. The trust and reputation parameters are included in the method to encourage more active prosumers to participate in energy trading for the long run.

Phase 5.4: Prosumer fair billing

Based on the quantitative analysis of the differentiated consumption and sharing behaviour of prosumers in phase 1, this step takes into account the uncertainty of consumers. A differentiated pricing scheme based on game theory is being developed in the step, which is essential for encouraging different categories of prosumers to participate in the coalition by providing them with a list of price plans (options). The quadratic and piecewise linear functions are used in these pricing methods.

Based on game theory, a detailed model of the requirements analysis process is presented for forming a coalition among prosumers and developing an optimised model of the prosumer energy management system, as shown in Fig.2.

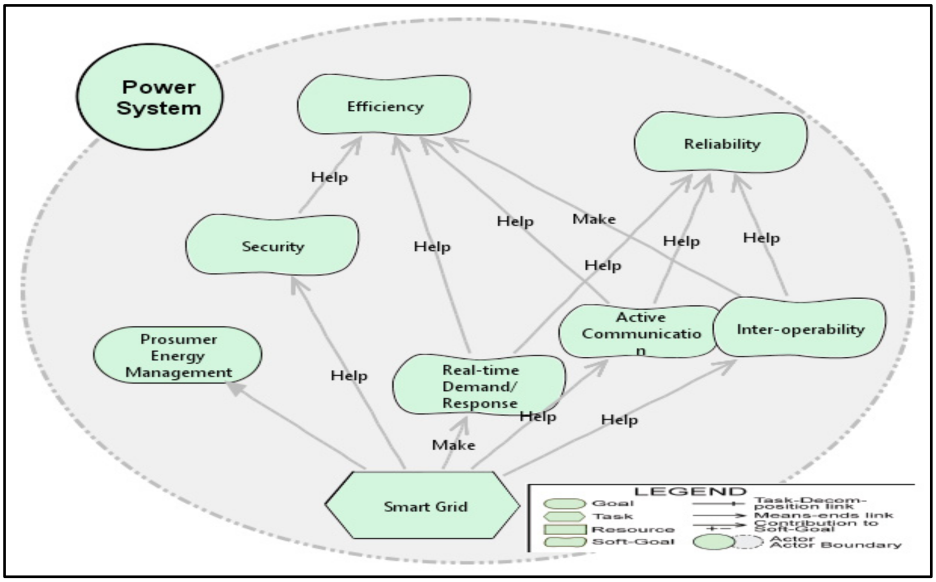

Figure 2. A game theory model depicted for prosumer energy management

The Strategic Rationale (SR) model, which is depicted in the form of a graph, is used for capturing and displaying the internal modelling of coalition formation and analysis of the actors in the framework. Non-functional goals or softgoals form the intended qualities of the system. Through the graph, nodes are represented as goals or tasks or resources or softgoals that are inter-connected by means-end links or task decomposition links or contribution links.

The goals are connected to one or more tasks through AND (decomposition links) or OR (means-end links) relationships for accomplishing it. The contribution links can be *Make; Break; Help; Hurt; Some+; Some-*. The developed goal model shows an actor, Power System that is considerably simplified but nevertheless requires some reasoning namely identification and exploration of alternatives. The goal model is an alternative smart-grid. The task of the requirement-analyst is to bring about maximum satisfaction to the non-functional requirements that are represented by softgoals.

Practical level: We propose to validate the recommended model and verify the method using real-world scenarios. Firstly, the algorithms in each phase are verified in Matlab Simulation Environment that can perform visualisation of energy data, graphical analysis of output and computation of numeric data. Secondly, a prototype of the developed algorithms is prepared in conformity to combine methods within a platform by applying tools like Java, PHP and MySQL. The research on the specific topic of dynamic prosumer coalition based approaches in the smart grid has not been published so far.

6. Evaluation and Implementation

Lately, because of the increased influx of green energy resources in smart grid, power producers and consumers who are involved in renewable energy management, play a more dynamic role in distributing power in the smart grid. They are known as prosumers in the retail power market. Assessment of the proposed strategies is made either by utilising the generated data or real operational data that are publicly accessible. Real life scenarios are used to demonstrate the accuracy of the recommended model and the viability of its method. The Matlab Simulation Environment conducts energy data visualisation, calculation of numeric data and conducts a graphical analysis of output. The algorithms that are developed in each phase are tested in this environment. Also, a model of the developed algorithms is created in accordance to combine methods by using tools such as Java, PHP and MySQL. We intend to compare the existing methods and the proposed method in terms of performance of grouped prosumers coalition model based on game theory with the conventional heuristic based schemes. We propose to use various data analytics and technology tools for evaluation and implementation of the framework.

7. Conclusion, Recommendation and Future Outlook

We propose a novel dynamic, decentralised prosumer coalition formation method based on game theory that can satisfy utility grid demands. A conceptual framework is developed for coalition formation and energy management among prosumers in a dynamic environment. The approach has the potential to increase the size and number of coalitions, as more active prosumers join without a central controller to better manage the renewable energy usage and trading with energy buyers. We also develop a fair pricing method for the supplied energy based on the type of demand. Assessment of the proposed strategies is made either by utilising the generated data or utilising the real data that are publicly accessible. We validate the performance of adopting a game theoretic approach, comparable to the conventional heuristic based schemes.

References

[1] Bari A, Jiang J, Saad W, Jaekel A. Challenges in the Smart Grid Applications: An Overview. International Journal of Distributed Sensor Networks 2014;10:974682. doi:10.1155/2014/974682.

[2] Gao J, Xiao Y, Liu J, Liang W, Chen CLP. A Survey of Communication/Networking in Smart Grids. Future Gener Comput Syst 2012;28:391–404. doi:10.1016/j.future.2011.04.014.

[3] El Rahi G, Saad W, Glass A, Mandayam NB, Poor HV. Prospect theory for prosumer-centric energy trading in the smart grid. Innovative Smart Grid Technologies Conference (ISGT), 2016 IEEE Power & Energy Society, IEEE; 2016, p. 1–5.

[4] Capodieci N, Pagani GA, Cabri G, Aiello M. Smart Meter Aware Domestic Energy Trading Agents. Proceedings of the 2011 Workshop on E-energy Market Challenge, New York, NY, USA: ACM; 2011, p. 1–10. doi:10.1145/1998640.1998641.

[5] Ulbig A, Rullan T, Koch S, Ferrucci F. Assessment of Aggregated Impacts of Prosumer Behaviour 2016.

[6] Wang Y, Saad W, Han Z, Poor HV, Basar T. A Game-Theoretic Approach to Energy Trading in the Smart Grid. IEEE Transactions on Smart Grid 2014;5:1439–50. doi:10.1109/TSG.2013.2284664.

[7] Stern PC. Blind Spots in Policy Analysis: What Economics Doesn't Say about Energy Use. Journal of Policy Analysis and Management 1986;5:200–27. doi:10.2307/3323541.

[8] Kok K, Karnouskos S, Nestle D, Dimeas A, Weidlich A, Warmer C, et al. Smart houses for a smart grid. CIRED 2009 - 20th

International Conference and Exhibition on Electricity Distribution - Part 1, 2009, p. 1–4.
[9] Tompros S, Mouratidis N, Caragiozidis M, Hrasnica H, Gavras A. A Pervasive Network Architecture Featuring Intelligent Energy Management of Households. Proceedings of the 1st International Conference on PErvasive Technologies Related to Assistive Environments, New York, NY, USA: ACM; 2008, p. 75:1–75:6. doi:10.1145/1389586.1389673.
[10] Yik FWH, Burnett J, Prescott I. Predicting air-conditioning energy consumption of a group of buildings using different heat rejection methods. Energy and Buildings 2001;33:151–66. doi:10.1016/S0378-7788(00)00094-3.
[11] Chicco G, Napoli R, Piglione F. Comparisons among clustering techniques for electricity customer classification. IEEE Transactions on Power Systems 2006;21:933–40. doi:10.1109/TPWRS.2006.873122.
[12] Figueiredo V, Rodrigues F, Vale Z, Gouveia JB. An electric energy consumer characterization framework based on data mining techniques. IEEE Transactions on Power Systems 2005;20:596–602. doi:10.1109/TPWRS.2005.846234.
[13] Rathnayaka AJD, Potdar VM, Dillon T, Hussain O, Kuruppu S. Analysis of energy behaviour profiles of prosumers. IEEE 10th International Conference on Industrial Informatics, 2012, p. 236–41. doi:10.1109/INDIN.2012.6301138.
[14] Papaioannou T, Hatzi V, Koutsopoulos I. Optimal Design of Serious Games for Consumer Engagement in the Smart Grid. IEEE Transactions on Smart Grid 2016:1–1. doi:10.1109/TSG.2016.2582298.
[15] Miller S, Ramchurn SD, Rogers A. Optimal Decentralised Dispatch of Embedded Generation in the Smart Grid. Proceedings of the 11th International Conference on Autonomous Agents and Multiagent Systems - Volume 1, Richland, SC: International Foundation for Autonomous Agents and Multiagent Systems; 2012, p. 281–288.
[16] Bera S, Misra S, Chatterjee D. C2C: Community-Based Cooperative Energy Consumption in Smart Grid. IEEE Transactions on Smart Grid 2017;PP:1–1. doi:10.1109/TSG.2017.2653245.
[17] Wanyama T. Static and dynamic coalition formation in group-choice decision making. International Conference on Modeling Decisions for Artificial Intelligence, Springer; 2007, p. 45–56.
[18] Nguyen PH, Kling WL, Ribeiro PF. A Game Theory Strategy to Integrate Distributed Agent-Based Functions in Smart Grids. IEEE Transactions on Smart Grid 2013;4:568–76. doi:10.1109/TSG.2012.2236657.
[19] Mondal A, Misra S. Dynamic coalition formation in a smart grid: A game theoretic approach. Communications Workshops (ICC), 2013 IEEE International Conference on, IEEE; 2013, p. 1067–1071.
[20] Zhang B, Johari R, Rajagopal R. Competition and Coalition Formation of Renewable Power Producers. IEEE Transactions on Power Systems 2015;30:1624–32. doi:10.1109/TPWRS.2014.2385869.
[21] Razzaq S, Zafar R, Khan N, Butt A, Mahmood A. A Novel Prosumer-Based Energy Sharing and Management (PESM) Approach for Cooperative Demand Side Management (DSM) in Smart Grid. Applied Sciences 2016;6:275. doi:10.3390/app6100275.
[22] Vinyals M, Bistaffa F, Farinelli A, Rogers A. Stable coalition formation among energy consumers in the smart grid. Proceedings of the 3rd International Workshop on Agent Technologies for Energy Systems (ATES 2012), 2012.
[23] Mihailescu R-C, Klusch M, Ossowski S. eCOOP: Privacy-Preserving Dynamic Coalition Formation for Power Regulation in the Smart Grid. Agreement Technologies, Springer, Berlin, Heidelberg; 2013, p. 19–31. doi:10.1007/978-3-642-39860-5_3.
[24] Mihailescu R-C, Klusch M, Ossowski S. e COOP: privacy-preserving dynamic coalition formation for power regulation in the smart grid. Agreement Technologies, Springer; 2013, p. 19–31.
[25] Sha A, Aiello M. A Novel Strategy for Optimising Decentralised Energy Exchange for Prosumers. Energies 2016;9:554. doi:10.3390/en9070554.
[26] Lamparter S, Becher S, Fischer J-G. An Agent-based Market Platform for Smart Grids. Proceedings of the 9th International Conference on Autonomous Agents and Multiagent Systems: Industry Track, Richland, SC: International Foundation for Autonomous Agents and Multiagent Systems; 2010, p. 1689–1696.
[27] Block CA, Collins J, Ketter W, Weinhardt C. A multi-agent energy trading competition 2009.
[28] Celebi E, Fuller JD. Time-of-Use Pricing in Electricity Markets Under Different Market Structures. IEEE Transactions on Power Systems 2012;27:1170–81. doi:10.1109/TPWRS.2011.2180935.
[29] Ferreira R de S, Barroso LA, Lino PR, Carvalho MM, Valenzuela P. Time-of-Use Tariff Design Under Uncertainty in Price-Elasticities of Electricity Demand: A Stochastic Optimization Approach. IEEE Transactions on Smart Grid 2013;4:2285–95. doi:10.1109/TSG.2013.2241087.
[30] Li C, Tang S, Cao Y, Xu Y, Li Y, Li J, et al. A New Stepwise Power Tariff Model and Its Application for Residential Consumers in Regulated Electricity Markets. IEEE Transactions on Power Systems 2013;28:300–8. doi:10.1109/TPWRS.2012.2201264.
[31] Bhattacharya K, Bollen MHJ, Daalder JE. Real time optimal interruptible tariff mechanism incorporating utility-customer interactions. IEEE Transactions on Power Systems 2000;15:700–6. doi:10.1109/59.867162.
[32] Fahrioglu M, Alvarado FL. Designing incentive compatible contracts for effective demand management. IEEE Transactions on Power Systems 2000;15:1255–60. doi:10.1109/59.898098.
[33] Vlachos AG, Biskas PN. Demand Response in a Real-Time Balancing Market Clearing With Pay-As-Bid Pricing. IEEE Transactions on Smart Grid 2013;4:1966–75. doi:10.1109/TSG.2013.2256805.
[34] Zhong H, Xie L, Xia Q. Coupon Incentive-Based Demand Response: Theory and Case Study. IEEE Transactions on Power Systems 2013;28:1266–76. doi:10.1109/TPWRS.2012.2218665.
[35] Nunamaker JF, Chen M. Systems development in information systems research. Twenty-Third Annual Hawaii International Conference on System Sciences, vol. iii, 1990, p. 631–40 vol.3. doi:10.1109/HICSS.1990.205401.