A BLUEPRINT FOR THE COMBINATORIAL STRATEGY IN TRANSACTIVE ENERGY BASED CONTROL MECHANISM BY USING ENERGY FLEXIBILITY PLATFORM AND INTERFACE

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ABSTRACT

The strategic importance of Transactive Energy (TE) in World is steadily increasing, and therefore transactive control and coordination mechanism require effective strategy to achieve sustainable competitive advantages. Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis is one of the most effective approaches used for analysing strategic design of a system. In this study, structured SWOT analysis has been performed focusing on three advancements, namely PowerMatching, Intelligator and Energy Flexibility Platform and Interface, made in the area of transactive control and coordination mechanism. As a conclusion, applying the proposed methodology carries out effective combinatorial strategy planning for the TE-based coordination mechanism.

INTRODUCTION

Demand Response has been consistently ranked as one of the World's foremost research sector over the past 20 years. The outstanding advancements in demand response have been supported by advancement in smart appliances. Distributed generation and storage as well as process innovation within control mechanisms and coordination strategies. Advances in demand response and unbundling of power system have created opportunities to have Transactive Energy (TE) based coordination and control mechanisms. Therefore, multi-agent systems (MAS) have been proposed and investigated to implemented TE-based control mechanism in order to improve market responsiveness [1]. The developments in the demand response strategies, i.e. PowerMatcher, Intelligator and Energy Flexibility Platform and Interface (FPAI), towards Transactive Energy (TE) based coordination and control mechanisms focused exclusively different aspects in strengthening power system and providing advance solution for a variety of serious challenges, such as local balancing, decrease network congestions, demand shifting during peak hours and development in standardization etc.

PowerMatcher is multi-agent system that uses TE-based coordination and control mechanism in order to locally balance available distributed energy resources and dispatchable loads [2]. The main focus of the PowerMatcher is to prove the philosophy and concept of TE-based mechanism, i.e. the enablement of a variety of appliances to bid as per their marginal cost, which are aggregated at auctioneer agent and then transacted in electricity market via objective agent. On the other hand, Intelligator uses the same philosophy and concept, however it focused more on the advance algorithms to explain the challenges associated to demand dispatch of thermally dispatchable loads and electric vehicles [3],[4]. On the contrary, Energy Flexibility Platform and Interface (EF-Pi) is an effort to create an interoperable platform that is able to connect to a variety of appliances and support a host of demand response services such that physical appliances does not need to be changed when a consumer switches from one service to another. At the same time the Energy Flexibility Platform & Interface makes it easier for service providers to introduce new services without changing the physical system [5].

The combinatorial strategy is aimed at establishing a sustainable demand response scheme combining forces that determine TE-based control mechanism in particular, learning the competitive agents based environment in detail and strengthening the flexible alliance advantages for establishment of a successful strategy. Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis [6] is an effective means for analysing different approaches in order to attain systematic approach and supports for successful demand response strategy formulation. However, the conventional SWOT analysis is based on the qualitative method and has no means of identifying and evaluating the importance of SWOT factors analytically.

In this study, a qualitative SWOT analysis has been used to identify relationships among SWOT factors systematically and to formulate competitive strategy on the basis of identified relationships, and then analysed them means of methodology applied in the Analytic Hierarchy Process (AHP) [7]. Furthermore, the effectiveness of the proposed method and possibilities for its application to the competitive strategy formulation has been established.

SWOT FACTORS

In general, SWOT analysis is aimed at identifying the strengths and weaknesses of an approach/organization as well the opportunities and threats in the environment. However, in this study, set of SWOT factors is compiled by considering the mentioned smart grid developments. For this purpose, first key words were collected from the related research reports published so far on the PowerMatcher [2], Intelligator [3],[4] and EF-Pi [5], and then identified and classified into SWOT factors. The most influential strengths and weaknesses are shown in Table 1 and 2, and the most influential opportunities and threats are shown in Table 3 and 4, respectively.

Table 1: Strengths (S)	
(S_1)	Aggregator with high market competitiveness
(S_2)	Numerous competitive agents
(S_3)	Organization scalability
(S_4)	Heterogeneous demand resources within Multi-agent System
(S_5)	Flexibility to user's requirement
(S_6)	Fully-managed demand side management
(S_7)	Real-time demand dispatch
(S_8)	Learning for load scheduling
(S_9)	Active collaboration with agents
(S_{10})	Introduction of advance ICT
(S_{11})	Product development

Table 2: Weaknesses (W)	
(W_1)	Fluctuation in electricity market
(W_2)	Dependency on domestic trends of customer
(W_3)	Price competition in market
(W_4)	Limited intelligence within MAS
(W_5)	Low collaboration within MAS
(W_6)	Lack of accurate forecasting capability
(W_7)	Lack in standarization
(W_8)	Device specification dependency on performance
(W_9)	Limited system engineering
(W_{10})	Market and regulators conservative tendency towards advance technology

Table 3: Opportunities (O)	
(O_1)	Increasing versatility anf lexibility in network
(O_2)	Positive environmental effects
(O_3)	Customer empowerment
(O_4)	Trend of close collaboration between customer and sevice provider
(O_5)	Increasing energy transistion process
(O_6)	Increasing requirements of new and more advance technologies
(O_7)	R&D of innovative strategies, control and learning techniques
(O_8)	Progress of embedded componenets and parts developments

Table 4: Threats (T)	
(T_1)	Increasing e-security
(T_2)	Monopsony of large aggregator
(T_3)	Decrease in customer's direct control
(T_4)	Reorganization of power system
(T_5)	Mishandling or underutilizationf of big data
(T_6)	Increasing network challenges
(T_7)	Overdefining the system

QUALITATIVE SWOT METHODOLOGY

The conventional SWOT analysis is based on the qualitative analysis and has no means of determining the importance or intensity of SWOT factors analytically. As numerous criteria and interdependencies complicate the procedure of strategic planning, the utilization of conventional SWOT analysis has become insufficient. Saaty [7] developed a mathematical method for analysing complex decision problems with multiple criteria, named as Analytic Hierarchy Process (AHP). The AHP in SWOT analysis assigns qualitative weights to individual SWOT factors. In this method, AHP in SWOT analysis is presented as application of utilizing pairwise comparisons p_{ij}, which are carried out within SWOT groups in the form of the matrix as shown in equation.

$$p_{ij} = \begin{bmatrix} {}^{w_1}/_{w_1} & \cdots & {}^{w_1}/_{w_j} \\ \vdots & \ddots & \vdots \\ {}^{w_i}/_{w_1} & \cdots & {}^{w_i}/_{w_j} \end{bmatrix}$$

Where $p_{ij}$is an estimated ratio of the unknown weights ${}^{w_i}/_{w_j}$. The value of w may vary from 1 to 9; 1/1 indicates equal intensity/importance where as 9/1 indicates extreme or absolute intensity/importance.

In this study, the list of SWOT factors was analysed using the methods shown in Figure 1 to determine the intensity or priority order of each factor. In addition, multiple criteria consist of PowerMatcher and Intelligator performance measures.

In this study, criteria associated with PowerMatcher are:

(α_1) customer's satisfaction creating capability i.e. (EF-Pi),
(α_2) real-time demand dispatch in electricity market,
(α_3) scalable organization capability,
(α_4) strong Information Communication and Technology (ICT) as well as embedded device capability.

On the other hand, criteria associated with Intelligator are:

(β_1) advance learning capability,
(β_2) scheduling capability,
(β_3) network operational performance.

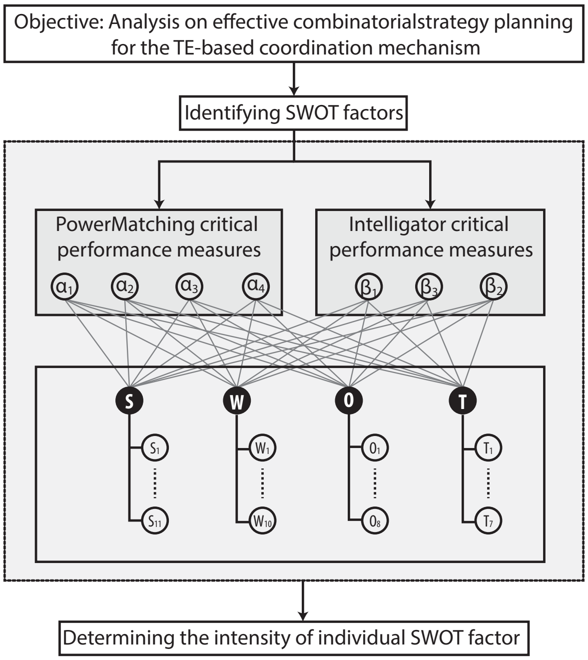

Figure 1. Basic concept of quantitative SWOT analysis [6].

It should be noted that here EF-Pi has been taken as one of the criteria in PowerMatcher. It is due to the fact that the effort of developing EF-Pi along with PowerMatcher developments. Moreover, for this study, combining EF-Pi with PowerMatcher also simplifies the presentation of SWOT evaluation as well. SWOT factors evaluated by multiple criteria are shown in Fig. Figure ***2*** (strengths), Figure 3 (weaknesses), Figure 4 (opportunities), and Figure 5 (threats). Furthermore, from Fig. Figure ***2*** and Figure 4 , by considering the given methodology it can be observed that the strengths and opportunities of PowerMatcher and Intelligator are clustered together, and are mostly rated low that implies they mostly have similar strengths of the mechanisms and opportunities in the environment. On the other hand, weaknesses and threats are relatively disperse, as shown in Figure 3 and Figure 5. Thus, it can be inferred that by combining these development, weaknesses of the overall approach reduces as well as it will also lower the threats to the environment.

COMBINATORIAL STRATEGIC PLANNING

Using the quantitative evaluated SWOT factors, effective combinatorial strategy planning for the TE-based coordination mechanism can be developed for the purpose of building on the strengths, eliminating the weaknesses, exploiting and/or countering the threats. Hence, the proposed quantitative SWOT analysis can provide an important foundation for the formulation of a successful strategy.

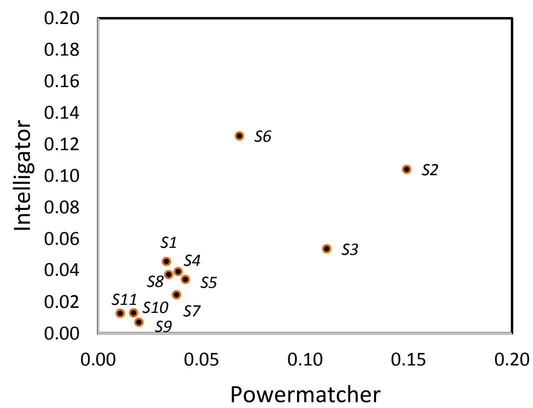

Figure 2. Evaluated performance of Strength.

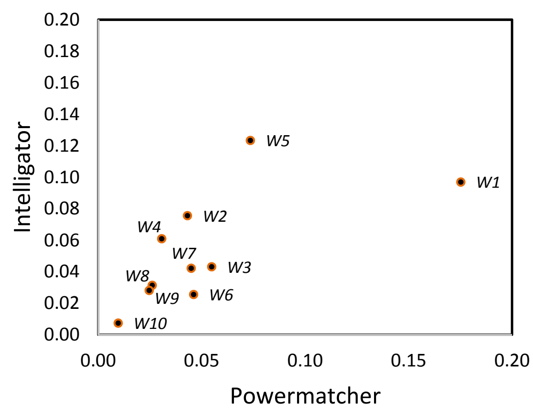

Figure 3. Evaluated performance of Weaknesses.

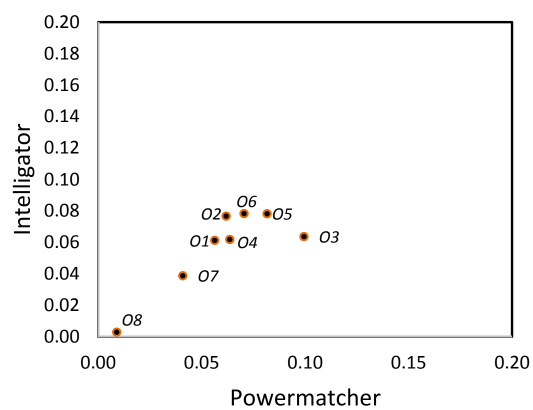

Figure 4. Evaluated performance of Opportunities.

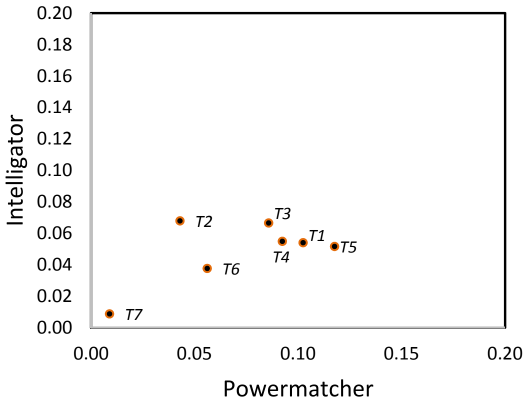

Figure 5. Evaluated performance of Threats.

By pairwise comparing the most influential SWOT factors, a resultant demand response strategy could be generated as shown in Figure 6. From this result, it is visibly implied that the global effectiveness would be the mutual region of market-related effectiveness, the system-related effectiveness and the product-related effectiveness. Moreover, the pairwise combination of these three effectiveness would take a broad view of the selected three smart grid development, namely PowerMatcher, Intelligator and FPAI. Thus, the all variety of smart grid developments are required simultaneously for reinforcing combinatorial strategy in order to achieve effective and sustainable TE-based mechanism.

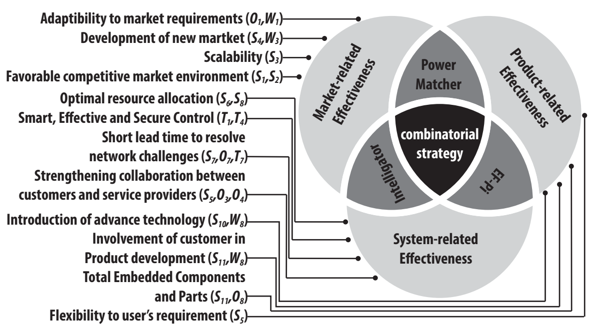

Figure 6. Combinatorial strategy for TE-based control and coordination mechanism.

Therefore, in order to rationally strengthen the combinatorial strategy effectiveness, it is indispensable to select and focus the available resources and developments as well as to acquire and realize the core competence in transactive coordination and control mechanism.

CONCLUSION

A structured methodology for identifying and analysing the SWOT factors of the TE-based coordination and control mechanism has been presented in this in this study. Based on the SWOT factors identified, successful combinatorial strategy could be achieved. As a conclusion, the following inferences could be drawn:

- ✓ SWOT factors of the TE-based coordination and control mechanism have been listed, and their critical features have been clarified.
- ✓ A qualitative SWOT analysis has been performed by weighing the individual SWOT factors using the pairwise comparison matrices.
- ✓ A combinatorial strategy planning for the TE-based coordination mechanism has been presented in the light of proposed analysis.

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