Applied Mechanics and Materials Vols. 284-287 (2013) pp 3612-3616
© (2013) Trans Tech Publications, Switzerland
doi:10.4028/www.scientific.net/AMM.284-287.3612

Multi-Dimensional Assessment for Residential Lighting Demand Side Management: A Proposed Framework

Yusak Tanoto[1, a], Murtiyanto Santoso[2, b], Emmy Hosea[3, c]

[1, 2, 3]Electrical Engineering Department, Petra Christian University, Surabaya 60236, Indonesia

[a]tanyusak@petra.ac.id, [b]murtis@petra.ac.id, [c]emmyho@petra.ac.id

Keywords: Lighting Demand Side Management, residential, multi-dimensional assessment.

Abstract. Effective Demand Side Management (DSM) practices require adequate assessment in which several important factors are taken into consideration. Criteria to measure DSM potential and set DSM targets are substantial to be well predefined. The aim of this paper is to propose assessment framework towards effective residential lighting demand side management planning. The assessment involves multi-dimensional factors comprising technical, economic, society preference, and environmental emission along with their mean of analysis. Technical dimension in terms of electricity demand is analyzed using Baseline Energy Use method whereas Life Cycle Cost analysis along with Cost-Benefit Assessment are used to calculate economic cost and other parameters during the project lifetime. Multi-criteria decision making using Analytic Hierarchy Process is performed to capture customer preference on selecting the preferable DSM loading scheme. In addition, environmental emission reduction potential is revealed using End-use Electricity Saving method.

Introduction

Utilization of electricity energy has been growing rapidly over decades, especially in developing countries. To meet the ever growing demand, generation capacity expansion which has been highly dependent on fossil fuels often selected as practical solution. Nowadays, the need for meeting power demand through conventional power generation expansion is facing climate change and global warming issues, in addition to the non-renewable resources depletion. Since its introduction in the late 1980s, Demand Side Management (DSM) has been viewed as promising approach to reduce electricity consumption. In general, the costs incurred during the program duration could be exceeded by the potential power generation that can be avoided. Energy saving in domestic sector obtained from demand reduction can be predicted based on the specific DSM load profiling. However, each load in certain area has its own characteristic that may be different from other areas. Therefore, a well-suited DSM strategy has to be developed to match specific load condition.

This paper proposes assessment framework towards effective DSM program. The framework is specifically focused to be utilized by utility and decision maker as guidance in planning the lighting residential DSM. Section 2 addresses DSM implementation opportunity to ensure the program effectiveness and maximum benefits. The lighting DSM is further discussed in Section 3. Elaboration of the proposed assessment framework is given in Section 4. Finally, conclusion is presented at the end of this paper.

The Need for an Effective DSM

DSM has been traditionally seen as a means of reducing peak electricity demand so that utilities can delay building further power generation capacity [1]. Other benefits include emissions mitigation and ability to defer high investments in generation expansion. Applying DSM to reduce end-user energy demand shall provide significant system reliability, economic and environmental benefits only if it is well prepared and thoroughly examined. Historically, the opportunity to increase power system efficiency and the high cost incurred in the power system has been the key drivers to introduce DSM [2]. The development of information and communication technology (ICT) has encouraged increasing efficiency of power system in both supply and demand areas. Besides, the increasing energy price remains a great challenge for many energy imported countries. Geopolitical tensions have worsened the situation and thus threatened the countries' energy security. Development of ICT and increasing energy price may not become primary reasons to adopt DSM. The ICT development could be beneficial if the high-end ICT infrastructure with their supporting power system equipment was available. Meanwhile, increasing energy price only gives few effects or even nothing to the rich energy resources countries. Nevertheless, climate change and global warming phenomena are actual issues that are eventually affecting many activities in all countries. Therefore, reason for implementing DSM in different region or country can be different, having considered the DSM key drivers. International Energy Agency (IEA) conducted a survey in 14 OECD Countries which resulting the top reasons given for implementing DSM [3]. In the developed countries, the so called "market-driven" reason is now becoming prominent as utilities strive to provide reliable service in a competitive market. For developing countries, DSM implementation has been one of major discussions as those countries are struggling to increase efficiency in power system operation and end-use appliance. In addition, electricity and energy price subsidy are other problems yet to overcome. Thus, the main reasons for implementing DSM in most developing countries are end-use energy efficiency and reducing cost-related electricity supply. With emphasis to improve end-use energy efficiency, developing countries are facing limited numbers of technology selections. Besides, not all technologies are feasible to be used in the developing countries.

DSM objectives may spread over the simplest to the complex ones depending on the program scope and complexity of technology being used. However, power demand reduction is usually one of the ultimate objectives. In this regard, thorough assessment based on clear criteria is prominent in order to determine certain target. Careful consideration should be given to define program potential criteria sufficiency and priority since the program budget must be effectively and efficiently allocated by looking at DSM program complexity level. Advance DSM program usually characterized by modern power infrastructure and ICT requirement whereas traditional DSM programs such as lighting and energy conservation require less. In turn, program potential criteria along with its associated target will be influenced by the level of the program.

Lighting DSM

In developing countries, numerous DSM studies as well as practices have proven that the energy efficient lighting (EEL) programs in the residential and commercial sectors are the most promising and popular DSM activities. The program is commonly implemented through the replacement of incandescent lamp or T-lamp with Compact Fluorescent lamp (CFL). Thailand successfully implemented a US$ 189 million DSM program in lighting. It successfully reduced peak demand by 238 MW and obtained cumulative annual energy saving of 1,427 GWh by the end of 1998 [4]. Mexico conducted lighting DSM program through Mexico High Efficiency Lighting Pilot Project in 1994. As reported [5], replacement of about 440,000 IL with CFL had resulted on 20 GWh saving and 4,000 tons CO_2 emission reduction/year. Vietnam has initiated DSM program started in 1997. The DSM program was designed through several phases including technical assistance and capacity building activities [6]. In Nepal, the DSM study found that the Net Present Value of the EEL program from the multi stakeholder perspective was positive and would help the country to cut power import, reduce power cost and electricity tariffs, and postpone the investment of new power plants [7].

Proposed Assessment Framework for Residential Lighting DSM

Several studies have worked with methods to assess the feasibility of conduction DSM program in particular Residential Lighting Demand Side Management (RLDSM). However, most of them used only single method and thus the result gave only partial understanding in terms of the need for applying RLDSM. In this research the proposed assessment framework for RLDSM consists of four main assessment parts consisting of technical, economic, society preference, and environment aspect, in which each part provides their distinctive output. Technical dimension in terms of residential lighting demand is analyzed using Baseline Energy Use (BEU) method whereas Life Cycle Cost (LCC) along with Cost-Benefit Assessment (CBA) is used to analyze economic feasibility. Cost evaluation using LCC in the case of lighting retrofitting can be served as the basis for further analysis and payback period based on the project lifetime. CBA allows comparison of the existing lighting system with the proposed one, in terms of energy and cost, which lead to assess the emission impact. Multi-criteria decision making (MCDM) using Analytic Hierarchy Process (AHP) [8] is performed to get customer preference in terms of the appropriate DSM loading scheme. In addition, environmental emission reduction potential is revealed using End-use Electricity Saving (EES) method. The authors have observed that LCC and EES are promising methods that have been applied to determine the emission mitigation potential resulting from the efficiency of electrical appliances [9]. The proposed assessment framework of RLDSM is presented in Fig. 1.

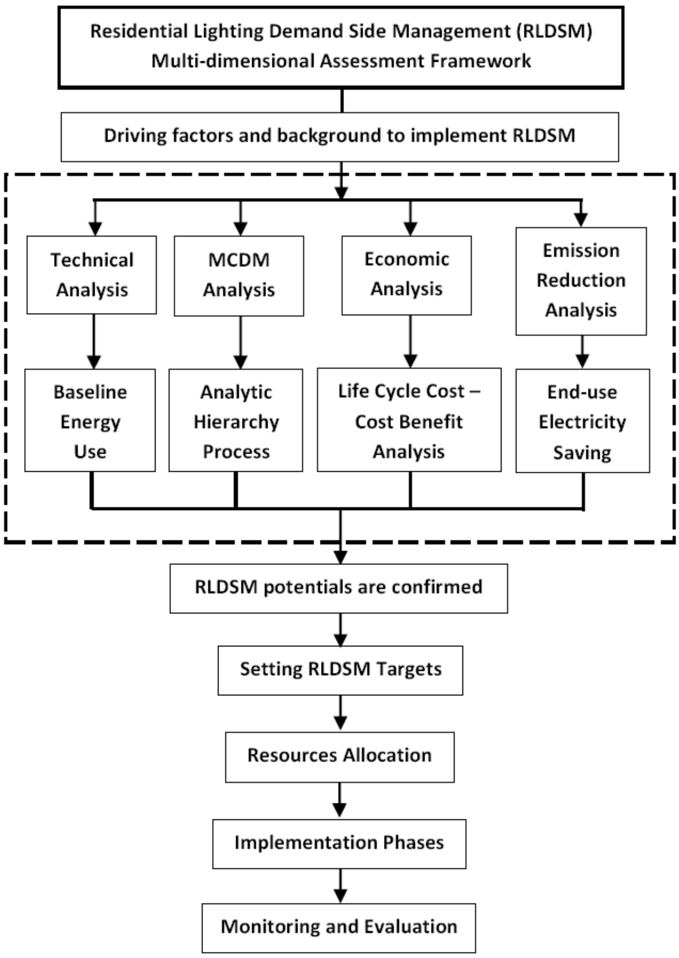

Fig. 1. The proposed multi-dimensional assessment framework of RLDSM.

The proposed framework consists of two main parts. The first one deals with assessment of the RLDSM program potential. Once all analyses are completed, the program potential can be wholly revealed. Prior to conducting the first part, a study summarized the driving factors and background to implement RLDSM should necessarily be conducted. The second part is essentially an extended mechanism which gives a continuation process to the already captured potential. It started by setting DSM targets followed by allocating the required resources. The opportunity of getting financial as well as technical assistance shall be finalized and come to the real cooperation activities. Implementation phases come afterwards, where the activities under the RLDSM are conducted in parallel with the monitoring phase.

Methodology to Apply the Proposed Framework. To begin the analysis, a region is first selected as the study area along with determination of participant boundary. The relevant data required for the analysis is initially obtained through a household and market survey as well as from the local utility. Data from utility regarding electricity system load should be collected to get a particular day when the highest peak load occurs. This information will then be useful for further analysis to obtain peak coincidence factor. Data collected from the household survey consists of general data and electricity consumption data. Some of them are electricity tariff class, monthly electricity consumption and corresponding bill, and more importantly load pattern of using lamps. This particular information is required to generate daily load profile associated with the lamp utilization. In addition, it is necessary to get the customer preferences in order to determine the appropriate DSM loading scheme under the MCDM analysis. Questionnaires are distributed over households, the number of which surveyed are determined based on the minimum sample sufficiency mentioned by Newbold [10]. Technical analysis using BEU method is performed as reference to calculate electricity utilization by lighting in the area of study. The compiled data based on the survey consisting of four essentials information: number of lamps of each lamp type, average number of lamps per household, total number of lamps in household and average daily operating hours for each lighting type is then analyzed to characterize the baseline energy use for the sample. The first information is used to estimate the total number of lamps available and is used further to determine the Diversity Factor (DF). The second information is calculated by noting the quantities of each lamp type and the number of sample size households. The third information depends on number of participant and average number of lamp per household. MCDM analysis through AHP is developed using three hierarchy classes. In the top hierarchy, the program goal is to select the most appropriate RLDSM strategy for the study area. The second hierarchy is placed with alternative DSM loading schemes which serve as alternative strategy whereas the last hierarchy filled with several criteria for the decision making, which are initially defined and included in the questionnaire sheet. Respondents are asked to determine their preference by selecting the criteria along with the scale. The appropriate strategy for the study area is determined from the most chosen strategy. In common practice, EEL has been proposed based solely on technical potential. In this sense, the replacement of existing with the energy efficient lamps is solely based on the similar characteristic of luminous flux of lamp. By doing so, the analysis would fail to capture the overall cost that might occur during the project life time. In the proposed assessment framework, economic feasibility in terms of the cost incurred is calculated using CBA and LCC analysis. Eventually, the proposed economic analysis would give the user selected energy efficient lamps based on the least LCC and the biggest benefit among alternatives. Emission reduction analysis which is carried out using EES aims to determine the potential reduction of CO_2 emissions resulting from the efficiency improvement with respect to parameters of the resulting energy savings and emission factor of power generation. The EES method is presented in Fig. 2.

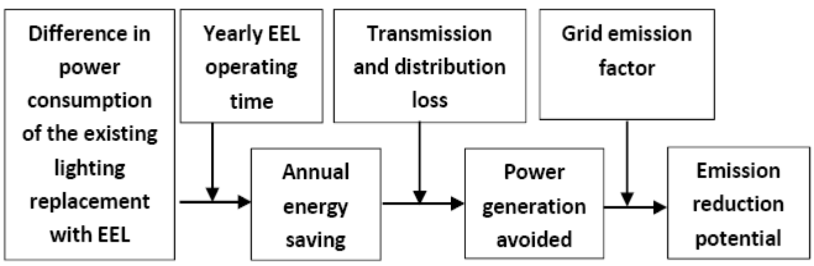

Fig. 2. End-use Electricity Saving method adopted for RLDSM.

Annual energy saving calculation considers DF since in the sample some fractions of the appliances are off. Meanwhile, total power consumption for selected EEL and existing lighting to be replaced with EEL is calculated by considering the estimated total number of lamps and lamp type. Technical power generation avoided is simply the power difference obtained from lighting replacement. The technical potential of CO_2 mitigation is calculated by considering the amount of energy saving by EEL and grid emission factor. In general, each analysis will contribute their intermediate result which required as input by other analyses. For instance, selected EEL obtained from economic analysis will determine the amount of annual energy saving calculated in the technical analysis. On the other hand, the selected RLDSM load profiling would also affect avoided power generation as well as avoided peak load.

Conclusion

The need for an effective DSM is addressed in this paper. Driving factors and background to implement RLDSM should be first realized as unique factors so that the prepared program can match the condition. This paper presents a proposed multi-dimensional assessment framework towards effective RLDSM. Overview to the proposed framework along with the methodology to apply the framework is presented accordingly. The framework is hence proposed as a guidance to assess RLDSM. The tools development along with framework implementation for the case study shall be presented in another paper.

Acknowledgements

The authors express their gratitude to the Directorate General of Higher Education, Ministry of Education and Culture of The Republic of Indonesia for providing grant to conduct this research under the Contract No. 0004/SP2H/PP/K7/2012, and No. 07/SP2H/PP/LPPM-UKP/II/2012.

References

[1] Information on http://africa-toolkit.reeep.org/modules/Module14.pdf

[2] G. Strbac: Demand Side Management: Benefits and Challenges. Energy Policy Vol. 36 (2008), p. 4419 – 4426.

[3] Information on http://www.ieadsm.org/Files/Tasks/Task%20I%20Subtask%208%20-%20International%20Database%20on%20Demand-Side%20Management%20Technologies%20and%20Programmes/Archive/indeep%20analysis%202004.pdf

[4] Information on http://www.esmap.org/esmap/sites/esmap.org/files/CS_DSM_Thailand21641.pdf

[5] Information on http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/1994/03/01/000009265_3970702134023/Rendered/INDEX/multi0page.txt

[6] Information on http://www.esmap.org/esmap/sites/esmap.org/files/58.%20GEF_DSM_PAD_122302.pdf

[7] M. Yang: Demand Side Management in Nepal. Energy Vol. 31 (2006), p. 2677 – 2698.

[8] T. L. Saaty: Decision Making With the Analytic Hierarchy Process. Int. J. Services Sciences Vol. 1, (2008), p. 83 – 98.

[9] R.M. Shrestha, W.K. Biswas and R. Shrestha: The Implication of Efficient Electrical Appliances for CO_2 Mitigation and Power Generation: The case of Nepal. International Journal Environment and Pollution Vol. 9 (1998), p. 237 – 252.

[10] Information on http://mpra.ub.uni-muenchen.de/23069/3/MPRA_paper_23069.pdf