UNIVERSITI TEKNOLOGI MARA

MULTI-BENEFIT COMPENSATION SCHEME DEVELOPMENT FOR GRID-CONNECTED SOLAR PV PROSUMERS USING CRITIC-TOPSIS

NUR IQTIYANI BINTI ILHAM

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ABSTRACT

A sustainable electricity grid requires strategic planning to optimize renewable energy adoption and its benefits. Despite rapid solar PV growth in Malaysia, challenges remain in optimizing compensation schemes with tariff structures and energy-sharing models, making it a relevant case study. Research on techno-economic and environmental impacts, including Battery Energy Storage Systems (BESS), remains scarce. The absence of dedicated evaluation tools complicates investment planning, highlighting the need for a comprehensive framework. Hence, this study develops an optimal solar PV compensation scheme and a novel Multi-Benefits Decision-Making (MBDM) index for PV investment planning, with or without BESS, and within energy-sharing communities. It considers various tariff structures (flat, Enhanced Time of Use (ETOU), and System Marginal Price (SMP)), compensation schemes (Self-Consumption (SELCO), Net Energy Metering (NEM 2.0, NEM 3.0)), multiple PV capacity sizes, and BESS autonomy hours. C1 commercial flat consumers are chosen to evaluate feasibility and impact. The Hybrid Optimization of Multiple Energy Resources (HOMER) Grid models solar PV compensation, with optimization results forming a decision matrix for MBDM index development. Indicators include environmental, energy, tariff, policy, and economic aspects. The CRiteria Importance Through Intercriteria Correlation (CRITIC) Weight (CW) and TOPSIS are combined to create CW-TOPSIS, verified against other Multi-Criteria Decision-Making (MCDM) methods. The study advances solar PV and BESS adoption by developing an innovative energy-sharing model with three (3) configurations: (i) grid-connected Solar Power Plant (SPP), (ii) grid-connected SPP with BESS, and (iii) grid-connected BESS. The model aims to decarbonize the Corporate Consumers (CC) community by considering different SPP and BESS capacities, wholesale SMP rates, and Scope 2 indirect emissions under the Greenhouse Gas (GHG) protocol. Findings show the NEM 2.0 with ETOU tariff (N2ET) is optimal, maximizing savings by balancing bill reduction, trading benefits, and MD mitigation. The most cost-effective system is 2-hour battery autonomy with 75% PV integration. The MBDM index consistently validates N2ET's superior performance, optimizing energy trading and financial benefits. For energy-sharing, Configuration II (SPP with BESS) is viable if Energy Storage Output to SPP Output Ratio (R) <16%, with 10% identified as optimal. Overall, the compensation scheme and MBDM index developed in this study are envisaged to enhance the benefits of solar PV adoption with better decision-making in investment planning, with or without BESS, and within energy-sharing communities.

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CHAPTER 1
INTRODUCTION

1.1 Research Background

The exploration of sustainable energy is now crucial as global temperatures and energy demand are simultaneously rising. Among the various renewable energy sources, solar PV has received significant attention for its ability to lower Greenhouse Gas (GHG) emissions and decrease reliance on fossil fuels. According to the 2015 Paris Agreement, three (3) enabling technologies for clean energy and achieving the 1.5°C climate target are Electric Vehicles (EV)/electric transportation, Energy Storage Systems (ESS) and solar photovoltaics (PV) [1]. The advancement of solar PV in electricity generation mix will keep developing to cater with the expanding population and rapid revolution in economic growth. With bounteous new technologies embraced and government support on policies and finances, sustainable and clean energy adoption is spurring globally. In Malaysia, the government is responsible for driving the adoption and development of solar energy through a variety of initiatives. These include fiscal incentives, supportive policies and regulations, interactive green taxes, low-interest loans, solar leasing programs, research grants, and public awareness campaigns. Together, these initiatives have cultivated an environment conducive to the growth of solar energy. The key to this progress is the Malaysian National Energy Transition Roadmap (NETR), which plays a crucial role in advancing Malaysia's energy transition and reducing greenhouse gas emissions through a diverse energy mix. The NETR aims to gradually increase the share of renewable energy, targeting 31% by 2025, 40% by 2035, and 70% by 2050. By 2050, it aims for a 32% reduction in GHG emissions compared to the 2019 baseline reaching 4.3 $MtCo_2eq$ emission per capita [2].

Over the past decade, Malaysia's grid-connected solar PV installations have experienced significant expansion, boasting a compound annual growth rate of 48%. This growth has seen the capacity rise from 0.1GW to 2.6GW [3]. In order to promote solar PV adoption, the incentives offered to consumers must be well attractive. Simultaneously, the policies planned should be significant to avoid any imbalance in electricity market and prices. In a comprehensive study conducted by Dusonchet and Telaretti [4], the authors analysed the impact of policy support on the solar PV progress