Facing Energy Trilemma with Solar Power Generation as Future Main Player in Infrastructure Development

Mohd Amran Mohd Radzi

Advanced Lightning, Power and Energy Research (ALPER) Centre, Faculty of Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

E-mail: amranmr@upm.edu.my

Abstract. Energy trilemma provides huge challenges for policy makers and implementers to reform the energy systems. One of the key efforts is to improve renewable energy (RE) participation, which is not only applicable in infrastructure development of urban areas, but also covering rural areas. Meanwhile, the growth of solar power generation can be seen clearly, and the increased generation could contribute significantly to supply electricity in both urban and rural areas with different challenges. Thus, this paper will address the strategies of facing Energy Trilemma and followed by role of photovoltaic (PV) systems in supplying electricity for urban and rural areas. The works done will be seen important equally in order to finally address full coverage of electricity with stable and reliable systems.

1. Introduction

Global energy systems are being reformed and restructured in facing climate change, digitalisation and changing consumer behaviour. The transition of the systems is analysed by the World Energy Council (WEC) through three core dimensions called the Energy Trilemma, which covers Energy Security, Energy Equity and Environmental Sustainability [1]. As a result, Energy Trilemma Index will be produced and published every year, that measures the overall performance of countries in achieving a sustainable mix of policies and the balance score highlights. Specifically, Malaysia moved up four places to rank 37 in the index, as reported in 2018. The index presents a comparative ranking of 128 countries’ energy systems.

There are many initiatives and efforts done to meet the need of this ranking. In term of electricity supply with special attention to renewable energy (RE), the strategies in each dimension of Energy Trilemma can be highlighted as below [2]:

i. Energy security: To enhance reliability, availability, efficiency and quality of electricity supply, and 20% is expected from RE mix by 2025.

ii. Environmental sustainability: To accelerate the decarbonisation of the electricity, which may include modern technologies in addition to RE.

iii. Energy equity: To ensure electricity is reasonably priced and benefits both consumers and producers.

Besides planning well at the supply part, ensuring all areas in a country to be covered by electricity is still a huge challenge. The urban areas may be electrified well, but the rural (isolated) areas could still be neglected. Therefore, providing electrical infrastructures in both areas may counter different challenges. People in urban areas are expecting modern grid infrastructure, including by considering
smart grid implementation. Smart grid is well known as a future of power grid which is able to manage generation, transmission and distribution of electricity by modern technology to counter various issues of current power grid systems [3]. Some of these issues are voltage sags, blackout, overloads and old grids which are also part of economic issue, and other factors especially carbon emissions which contribute to the environmental problem. Thus, considering both economic and environmental interests, implementation of smart grid will be significant. Modernization and upgrade of power grid by new facilities and latest products has been a reason for rapidly emerging of smart grid in many regions around the world especially in developed countries. As a developing country specifically, initiative on smart grid in Malaysia can be seen through installation of smart metering system following the implementation of the Advanced Metering Infrastructure (AMI) [2].

While there is a target of having increased capacity of renewable mix, balancing the infrastructure plan by considering the rural areas as important as urban areas is crucial. Thus, ensuring electricity coverage up to 100% is always becoming one of master plans of the government including in Malaysia. As power supply cannot be connected to the grid due to distance challenges, use of fuel-based generators are the common solutions. However, cost of fuel is very high and really needs to be subsidized [4]. Therefore, renewable energy systems could become alternative solution of ensuring all remote areas can be supplied by electricity.

In RE technology, solar photovoltaic (PV) shows the fastest growth. While it was very expensive previously, with the latest research and development outcomes, it will become affordable to be deployed in both urban and rural areas with different aim and targets. For the urban areas, limited spaces available for PV system may raise the concern on improving its efficiency especially on extracting power at maximum level from PV panel itself. Two major techniques are available: either by using sun tracking technique or use of maximum power point tracking (MPPT) technique. This paper concentrates on innovation in MPPT technique which is able to ensure power extraction at maximum level either in normal or extreme conditions. This innovation will directly improve infrastructure of the system itself. Meanwhile, for the rural areas, the discussion will cover the works on design of RE systems by mainly addressing role of PV system. It will also address the main concern on depending to PV system where the operation is fully capable and reliable to supply electricity independently.

2. Role of MPPT Techniques in PV System

A PV panel operates in nonlinear approach where there is only a single point of maximum power point (MPP) exists in power-voltage (P-V) curve as shown in figure 1. If multiple PV panels are connected, and partial shading occurs to a few of them, multiple peaks may exist. But there will be only single point as the highest one, known as global MPP (GMPP). Extracting power at this point needs a dedicated technique known as MPPT, and its functions can be shown in figure 2, as the simplest configuration of PV system. The MPPT technique will ensure the power is maximally extracted from PV panel for the converter to supply the load.
Various MPPT techniques have been proposed by researchers during the last decades, and these
techniques can be categorised based on the implementation methods into two groups, conventional and
intelligence computing algorithms [5]. In the case of uniform irradiation, the previous research works
have confirmed that conventional MPPT techniques can track the MPP efficiently, while under PSC
these techniques fail to guarantee effective tracking of the GMPP. In order to address operations under
PSC, further improvement is mandatory through modifications to the existing conventional tracking
algorithms as the first category, and the second category was established based on intelligence
computing methods. Newly formulated or improved P&O methods for MPPT were widely proposed
to improve the tracking process [6-7]. Alternatively, intelligence algorithms such as improved cuckoo
search (ICS) [8] and fuzzy logic [9] were also possible and have shown tremendous improvement.
Interestingly, both conventional and intelligence approaches could be combined as hybrid approach
[10].

To summarize, considerations of proposing novel MPPT techniques especially on operations under
PSC are algorithm’s complexity, tracking speed, required computation time, stability, oscillations
around the maximum extracted power, array dependency, and steady-state accuracy. The ideal
algorithm should be able to track GMPP accurately with high convergence speed as fast as possible,
with guaranteed stability over a wide range of weather fluctuations, having neglected oscillations
around the actual extracted power and also without any extra cost and complexity.

3. PV System in Rural Areas
In rural areas, the main concern of implementing PV system is its operational capability of supplying
electricity to residents there. Uncertainty in receiving sun radiation for generating energy may limit its
operation. Therefore, multiple RE sources can be considered for combination, as later known as hybrid
renewable energy systems (HRES). The reliability and cost of energy have improved in this combined units due to availability of many sources of energy to support each other in a cost-effective way. There are various configurations of HRES, and among them are [11]:

i. PV–wind–battery HRES: it is fully renewable sources with storage capacity. Understanding characteristics or sources and loads are important to ensure appropriate supply can be delivered without disturbances.

ii. PV–wind–diesel–battery HRES: diesel generator is still maintained with reduced consumption. In addition, it may be used for backup only for ensuring reliability of the system.

iii. Hydro sources either mini or micro hydro based systems can be considered for HRES as long as the locations are near to water sources. Definitely, the topography and speed of water will be very important factors for consideration.

iv. Use of bio-based sources such as biomass and biogas can be considered if the resources are available.

In various research works before, optimization works of obtaining the best configuration of system has widely been explored. Interestingly, many software tools are available in the market for assisting the designers to propose the system. The tools were comprehensively reviewed by highlighting features of each tool [12]. However out of all the reviewed software, HOMER, RETScreen, HYBRID2 and iHOGA are the best suitable for optimization. Among them, HOMER is a software which is widely used and is the most effective. It gives the wide range of components to optimize and also gives results in the form of technical, emission and economic analysis.

4. Conclusion

This paper has addressed the need to balance development of electricity infrastructures in both urban and rural areas, especially in facing energy trilemma. PV system used in urban areas are dealing with various performance issues with limited space available, and MPPT is one the significant works done to improve performance of PV system. Meanwhile, PV system in rural areas can be optimised with other possible RE sources for improving reliability of the system. With the reduced production price of PV component and system, it is expected that this technology will become the main player in development of future electrical infrastructures.

5. References

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