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Future strategic plan analysis for integrating distributed renewable generation to smart grid through wireless sensor network: Malaysia prospect

S. Zahurul [a], N. Mariun [a], I.V. Grozescu [b], Hanamoto Tsuyoshi [d], Yasunori Mitani [d], M.L. Othman [a], H. Hizam [a], I.Z. Abidin [c]

[a] Centre for Advanced Power and Energy Research, Faculty of Engineering, Universiti Putra Malaysia, Serdang 43400, Malaysia
[b] Faculty of Science, Universiti Putra Malaysia, Serdang 43400, Malaysia
[c] Electrical Power Engineering, Universiti Tenaga Nasional, Kajang 43000, Malaysia
[d] Kyushu Institute of Technology, Kitakyushu, Fukuoka 804-8550, Japan

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ABSTRACT

Integration of Distributed Renewable Generation (DRG) to the future Smart Grid (SG) is one of the important considerations that is highly prioritized in the SG development roadmap by most of the countries including Malaysia. The plausible way of this integration is the enhancement of information and bidirectional communication infrastructure for energy monitoring and controlling facilities. However, urgency of data delivery through maintaining critical time condition is not crucial in these facilities. In this paper, we have surveyed state-of-the-art protocols for different Wireless Sensor Networks (WSNs) with the aim of realizing communication infrastructure for DRG in Malaysia. Based on the analytical results from surveys, data communication for DRG should be efficient, flexible, reliable, cost effective, and secured. To meet this achievement, IEEE802.15.4 supported ZigBee PRO protocol together with sensors and embedded system is shown as Wireless Sensor (WS) for DRG bidirectional network with prospect of attaining data monitoring facilities. The prospect towards utilizing ZigBee PRO protocol can be a cost effective option for full integration of intelligent DRG and small scale Building-Integrated Photovoltaic (BIPV)/Feed-in-Tariff (FiT) under SG roadmap (Phase4: 2016–2017) conducted by Malaysia national utility company, Tenaga Nasional Berhad (TNB). Moreover, we have provided a direction to utilize the effectiveness of ZigBee-WS network with the existing optical communication backbone for data importing from the end DRG site to the TNB control center. A comparative study is carried out among developing countries on recent trends of SG progress which reveals that some common projects like smart metering and DRG integration are on priority.

Contents

Abbreviations: AES, advanced encryption standard; AMI, advanced metering infrastructure; AMR, automatic meter reading; APL, application layer; BIPV, building-integrated photovoltaic; DRG, distributed renewable generation; FiT, feed-in-tariff; GPRS, general packet radio service; GPS, global positioning system; ICT, information and communication technology; LOS, line of sight; NWL, network layer; PAN, personal area network; PHEV, plug-in-hybrid electrical vehicle; PLC, power line communication; RE, renewable energy; SCADA, supervisory control and data acquisition; SG, smart grid; TNB, Tenaga Nasional Berhad; WEP, wired equivalent security; WiMAX, worldwide interoperability for microwave access; WLAN, wireless local area network; WS, wireless sensor; WSN, wireless sensor network

E-mail addresses: zahurul2003_du@yahoo.com (S. Zahurul), norman@upm.edu.my (N. Mariun).

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1. Introduction

Environmental impact is a challenge due to carbon emissions and greenhouse effect from fossil fuels that has grown over the past ten years about 4–5 times greater than for the preceding 10 years. The consequences of global warming disturb natural ecosystem such as melting polar ice caps and mountain glaciers, rising sea level, and coastal inundation that would alter forests, crop yields, water supplies, and could lead to famine [1,2]. Taking these environmental issues as concern, the Prime Minister of Malaysia announced at United Nation Climate Summit (September 2014) to pursue the establishment of targeting 40% reduction in CO_2 emissions that was made in the 2009 Copenhagen Climate Change Convention through new policies towards a cleaner and sustainable future. This has also added a dimension to the tenth Malaysia plan (2011–2015) to reduce CO_2 emission per capita from 6.7 tones (data on 2007) to a minimum level. To establish this plan, the government has taken an initiative to produce 985 MW Renewable Energy (RE) by installing large scale Distributed Renewable Generation (DRG) as well as Feed-in-Tariff (FiT) in 2015. Malaysia national utility company, Tenaga Nasional Berhad (TNB) is continuing research on Smart Grid (SG) or intelligent grid system where large scale DRG (for instance, TNB initiated 50 MW solar power plant in province of Kedah) and FiT (1–5 MW for 21 years applicable to specific RE sources set by Sustainable Energy Development Authority of Malaysia) will be integrated. With this, TNB has pointed out that the challenge of finding solution for electricity generation from RE power plants has to be effectively and efficiently integrated into the national grid for providing reliable and uninterrupted electricity to the consumers [3–5].

SG is the future intelligent and fully automated energy management system where a bidirectional communication is the fundamental requirement for integrating Advanced Metering Infrastructure (AMI), distributed generation, power generation monitoring and regulation, and demand management [4,6–8]. However, like many other countries, Malaysia's existing power grid is not yet improved with current generation information and communication technologies; so a unidirectional energy flow from generation to the consumer persists. Due to the lack of bidirectional communication technologies in SG, TNB is not having real-time information about actual DRG or FiT production that fluctuates with climate change. In this situation, TNB cannot balance between the consumer load and the supply of electricity through demand management and energy forecasting program. Also, TNB control center is neither able to detect any fraudulent act or tampering with FiT meter nor disconnect it remotely. With this, TNB cannot motivate its consumers to reduce the consumption at peak-hour by updating their real-time FiT production in energy portal/mobile apps (some studies show 5–15% energy reduction is possible [8] by applying this method). However, there are some challenges in implementing the DRG/FiT data communication in Malaysian perspective. To start with, DRGs are currently situated at different remote locations where wired communication infrastructure may not be feasible or cost effective. For instance, 10.25 MW solar power plant in Negeri Sembilan is already commissioned at the southern part and another 50 MW will be implemented at Kedah, northern part of peninsular Malaysia. In addition, FiT and other small DRGs are scattered all over the peninsular and Borneo Malaysia. To integrate these remote locations to the TNB control center, wireless technology at the distribution area could be more viable and inexpensive than wired communication.

To develop both FiT and DRG communication networks, wireless communication technology can be considered because its ease of installation and lower operating cost. However, it has limitation on interference and spectrum resource [9]. In spite of these constraints, wireless technology is recommended as it is more feasible and advantageous over wired-line technology, based on the network structure analysis of SG by many researchers [10–13]. ZigBee or ZigBee PRO is one of the wireless technologies recognized by IEEE802.15.4 standard. It is facilitated by low power energy consumption, inexpensive, better coverage, simpler wireless connectivity, and relaxed throughput. Moreover, it supports one of the unlicensed frequency bands 2.4 GHz suitable in Malaysia. ZigBee PRO is the latest released device (October 2007) that has additional facility over ZigBee such as bigger memory size, higher number of nodes integration, multicasting capability, and higher security [14].

In general, ZigBee offers better capabilities over Wi-Fi with respect to energy consumption in sensor based mesh network. Even though ZigBee has low data rate and vulnerability to interference when co-existing with Wi-Fi, it is proposed by many researchers in various applications of SG where urgent and critical data demand is not crucial [14–20]. Based on these researchers, the communication backbone of the SG which links the DRG and the control center should be wired-line. Batista et al. [15] have tested ZigBee implementation in solar, wind, and also home energy management system where in general no significant interference with other transmission and power signal is detected. However, there are some researches that have addressed the interference problem between ZigBee and Wi-Fi and have it resolved [21–23]. A delay sensitive data of wind turbine are monitored through ZigBee-Wireless Sensor (WS) for ensuring that DRG detects the inaccuracies of the system [20]. The performance of 15 ZigBee WSN nodes is analyzed under different spectrum environments and concluded based on statistical analysis that ZigBee-WS can only be utilized in lower requirement of data rate and power application of SG [14]. Byun et al. have proposed a smart energy distribution and management system where ZigBee is particularly used for controlling and remote switching of the