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Application of load shedding schemes for distribution network connected with distributed generation: A review

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ABSTRACT

Islanding operation in a distribution network connected to Distributed Generations (DGs) has the advantage of being able to continuously supply power to the loads even when disconnected from the grid. However, there are technical issues that need to be solved in order to guarantee a successful islanding operation. The main challenge in the successful islanding operation is to ensure the stability of frequency and voltage of the distribution system. Commonly load shedding schemes are used as a mechanism to stabilize the magnitude of the frequency and the voltage by shedding some of the loads to ensure an adequate balance between generation and loads. This paper reviews recent load shedding schemes focusing on distribution system application. Their respective merits and demerits are presented. Moreover, this paper also highlights the application of Voltage Stability (VS) index for load shedding schemes. A brief overview of the DG with their respective advantages also presented at the beginning of this paper.

1. Introduction

The economic development and sustainability of any country around the world is measured by its energy production. Commonly, every country produces majority of its energy from fossil fuels resources. According to the International Energy Agency, the total energy consumption in the world is mainly from fossil fuel which accounts for 78%, whereby 39.9% from crude oil, 15.1% natural gas, 12.2% biofuels and 11.4% coal in 2014 [1]. Excessive use of fossil fuels has resulted in climate change due to greenhouse emissions, carbon emissions, sulphur dioxide and nitrogen dioxide emissions. Fig. 1 shows the carbon emission of different developed and developing countries [2]. It can be noticed from this data that USA and China also suffer from high carbon emissions. Due to these environmental concerns, every country aims to reduce their carbon emissions by replacing the fossil fuels through Distributed Generation (DG) based on Renewable Energy (RE) resources [3]. This type of DG has great potential in achieving the low-carbon emission due to its environmental friendly operation and its advantages are summarized in Fig. 2 [4,5].

Based upon these advantages, the interconnection of DG into distribution networks is undergoing rapidly around the world. Statistical data had proven this trend. For example, the European Union had set a target to replace 20% of the electricity generated from fossil fuels with RE sources by 2020 [6]. In the North Africa, the total RE consumption has increased from 27 to 97.1 Million tone from 2006 to 2016 [7]. Despite these advantages, the increasing trend of DG penetration in power system network causes certain technical issues, which needs to be resolved. These issues are summarized in Fig. 3.

Among these issues, islanding is one of the main challenge for fully utilization of DG based on RE. When islanding occurs as shown in Fig. 4, the power generation must be capable of maintaining stability, reliability, and power quality, for ensuring voltages and frequencies within the acceptable range. Otherwise, the islanded network will experience blackouts due to the trip off DGs for technical and safety reason. Islanding may occur unintentionally as well as intentionally. The unintentional islands may encounter active or reactive power deficiency, which may lead to frequency, angle, or voltage instabilities. This will inevitably expose distribution network to risks and hazards, especially to the equipment [8], utility liability concerns, and the reduction of power reliability and quality. However, this issue may be solved through effective intentional islanding strategy. An intentional islanding of a distribution system connected with DG has becomes a topic of interests to ensure successful operation of an islanded distribution system.

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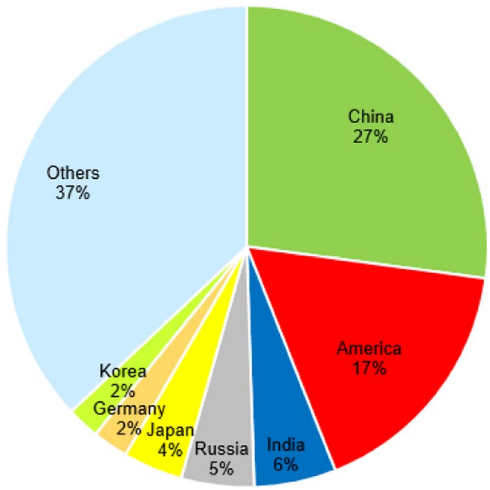

Fig. 1. Carbon emission for several countries.

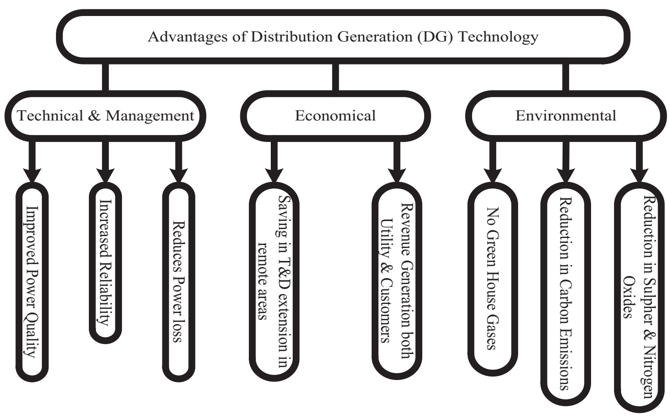

Fig. 2. Advantages of DG.

The successful islanding operation of the distribution network is closely related to the power system stability. The stability of power system network can be defined as "*The ability of power system returns to its nominal or stable operation after having been subjected to some form of disturbances*" [9]. The power system stability can be classified into 3 main groups, which are rotor angle stability, frequency stability, and voltage stability [10] as discussed in Table 1. With the increasing number of DG, maintaining the synchronisation of the power system following a disturbance becoming more challenging. For this reason,

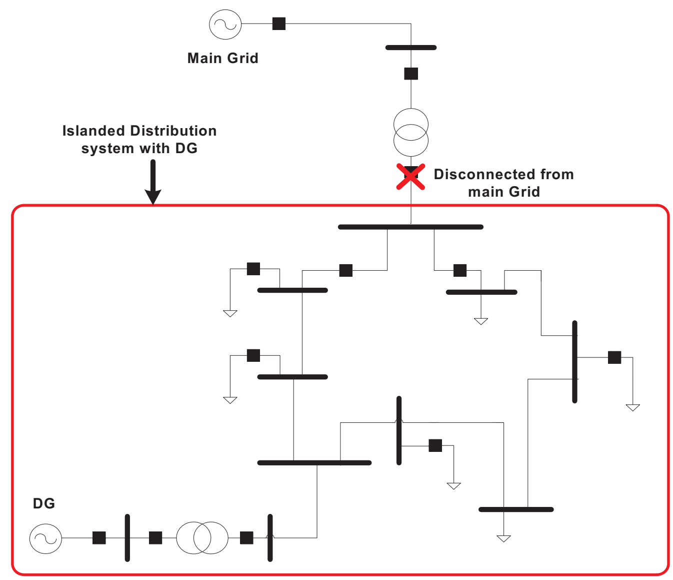

Fig. 4. Operation of DG in islanding mode.

effective controls are necessary to ensure a safe and reliable operation of distribution system to avoid system blackouts.

Another important factor for successful intentional islanding operation is to ensure power generation from DGs fulfils load demands. In the case where power generation unable to cope with load demands during operation, the last resort is to apply load shedding by removing some of the load from the system until balance between generation and load demands is achieved. Ineffective load shedding could lead to a high number of loads being shed or may lead to total power collapse. Therefore, effective load shedding scheme is needed to disconnect correct amount of load and avoid power system from blackout. Load shedding scheme should be simple, efficient, and decisive [11]. Table 2 summarized the requirements in ensuring the successful of load shedding operation. Various load shedding techniques have been proposed in the past. In general, these techniques can be categorized into Under Frequency Load Shedding (UFLS) scheme and Under Voltage Load Shedding (UVLS) scheme. The UFLS is initiated according to the system frequency changes while the UVLS is applied based on the changes of the voltage magnitude. Under this scheme there are three categories; conventional, adaptive and intelligent [12–14]. The reviews on each scheme are described in this paper. In addition, this paper also highlights the application of VS index for load shedding schemes.

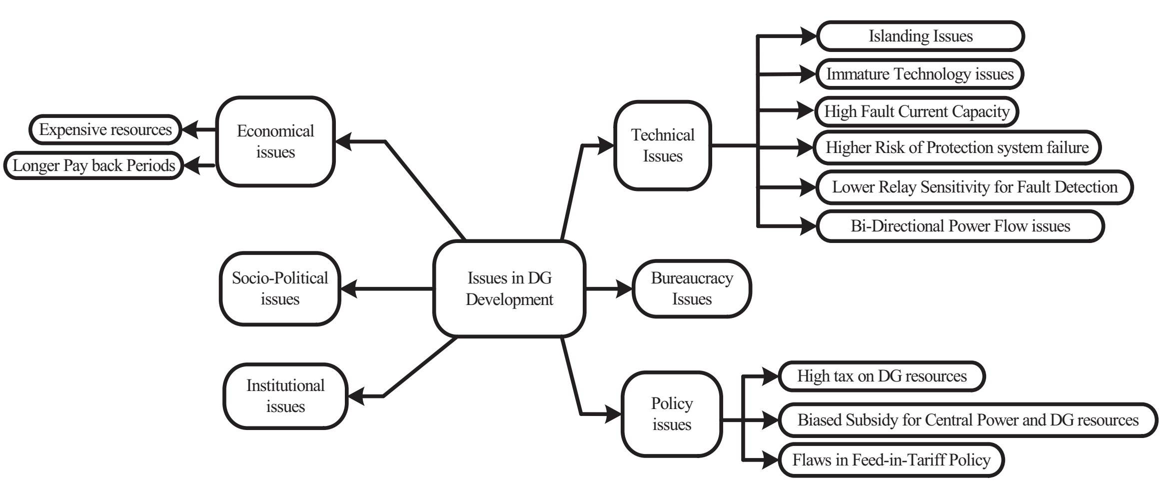

Fig. 3. Issues in the DG development.