Analysis of Large Scale Distributed Generation on Radial Distribution System: Case Study in Sri Lanka

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Abstract— **Large-scale penetration of distributed resources is becoming a reality in many parts of the world. Large scale renewable distributed generation has challenges at the distribution level and significant work is done to optimize the generation to ensure improved grid functionality. This work focuses on analyzing the protection and reliability of large-scale penetration of solar PV system in lightly loaded distribution feeders. This work considers an actual feeder in Vavuniya, Sri Lanka with 10 MW solar plant. To identify the impacts to the distribution system, fault study was carried with back-feeding to the grid and impact on system reliability was evaluated using expected energy not-served. A solution based on the placement of reclosers, circuit breakers and fuses is proposed in this work.**

Index Terms—**Distributed generation; large scale DR; protection coordination; expected energy not served**

I. INTRODUCTION

Recent technological advancements in terms of large-scale renewable penetration, dynamic loads such as electric vehicle charging and cyber infrastructure have increased the complexity of the system [1]. In addition, environmental considerations are gaining significant interest in multiple regions in the world. For example, according to the Sri Lanka Sustainable Energy Authority, "Sri Lanka is aspiring to become a carbon neutral country by 2050." Sri Lanka is a small island with a peak demand around 2500 MW [2]. Currently 42% of the installed capacity hydropower and rest from fossil fuel mainly oil. Grid connected large scale distributed solar and wind are in the increase.

These DGs on the distribution network can have a significant impact on the system such as voltage fluctuations, voltage sag and swells, frequency variations, protection coordination and reliability [3–7]. Therefore, according to Zamora, et al., the existing distribution system must undergo a restructuring process to maintain its ability to serve its customers uninterruptedly and in harmony with the existing grid [3].

Due to the unpredictability of the distributed resources and back-feeding improvement to protection schemes is necessary. Bhise, et al., demonstrations higher level of DG penetration to the network would have a significant effect on the protection if they are not properly coordinated [8]. Furthermore, poor design coordination or improvements of protective devices on the distribution network will result in loss of revenue both at the substation level and on DG level. Preventing losses to the consumers is important and must take necessary action to mitigate such occurrences.

The optimal placement and sizing of DG must be analyzed to maximize the penetration of DG in order to keep the existing protection scheme [9]. There are several approaches proposed to solve the coordination problem such as microprocessor-based reclosing system to coordinate reclosers and fuses [10], implementation of Thyristor Controlled Series Capacitor (TCSC) according to limit the fault current contribution of DG [11], support vector machine (SVM) based classifier for the relay setting [12], placing protective devices with a superconducting fault current limiter (SFCL) due to the application location of a DG [13], use of multi-agent based system [14] and dual setting directional over-current relays for protecting meshed distribution systems with DG [15].

This paper is focused on analyzing the impact on protection coordination caused by the 10MW solar plant in Sri Lanka through a fault study. The operation of protection devices is analyzed to suggest suitable protection devices for this system.

The remaining of this paper is organized as follows. Section II describes the distribution feeder system. The current system characteristics are shown in section III. Section IV represents the characteristics of the improved system with the placement of protection devices. Voltage drop analysis and protection coordination loss are discussed in section V. In section VI the conclusion is drawn.

II. DISTRIBUTION FEEDER SYSTEM

This analysis was done by considering the 33kV distribution system with a 10MW solar plant. The plant is connected in the feeder number five, at Nedunkulam, Vavuniya, which is a developing zone in Sri Lanka. The data of the system were collected from the Ceylon Electricity

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