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Integration of 750 MW renewable solar power to national grid of Pakistan – An economic and technical perspective

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ABSTRACT

The electrical power distribution network in Pakistan is a complex system with many geographical regions suffering from frequent blackouts, limited and intermittent supply. Investment in mega-scale solar energy generation projects could help mitigate these supply related problems and counterbalance the country's growing dependence on imported oil. The purpose of this paper is to explore the economic and technical impact of connecting a mega-scale PV plant to the national grid. The area of Kharan in Balochistan province was chosen due to desired solar irradiation (7–7.5 kW h/m^2/day). The simulations were carried out with existing and planned interconnected transmission system of Pakistan that has not been pre-designed to incorporate such intermittent generation. Load flow studies and short circuit analysis were carried out and it was established that power from this solar power project can be evacuated to the 220 KV system of National Transmission & Despatch Company (NTDC), Pakistan without any transmission constraints. The three phase and single phase short circuit current studies further confirmed reliable grid interconnection in terms of power quality indices. Furthermore recommendations encompassing the economics and technical sides are presented for the successful commissioning of this installation.

Contents

1. Introduction

Renewable energy resources are inevitable for sustainable economic and industrial growth. The consumption for energy continues to increase and renewable energy technologies are

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considered as clean and sustainable sources of energy due to minimum environmental impacts [1]. The primary energy sources including oil, coal and gas are anticipated to be depleted in the next 40–50 years and conventional electric power systems being dependent on large base-load power plants have limited ability to sweep output power level [2,3]. The future sustainable economies should have principal dependence on renewable energy resources and step-change transformation in energy production mechanisms both on economic and technical fronts. Similarly, Pakistan plans to cut its dependence on hydrocarbons, especially on imported coal, oil and gas, to around 60% by 2025 from the present 87% [4]. According to estimates, energy shortages have cost the country up to 4% of GDP over the past few years [5] and on-hand indigenous energy resources in Pakistan are scarce. The mitigation requires political will, additional funding, and new renewable power-generation projects based on economic and technical feasibilities. To meet the acute energy shortfall, power generation through large-scale renewable ventures involving solar and wind energy are preferred and resulting impacts on power systems are promising [6]. The technologically viable options in Pakistan include: micro-hydel, bio-energy, wind and solar energy. But generation of power from hydro, wind and bio-energy sources is confined to sites where these resources are readily available and can be processed on-site; whereas solar energy can be effectively extended to both rural and urban areas [6,7]. Solar energy provides cost-effective solution to energy crisis in Pakistan as compared to wind energy based projects [7]. Solar energy alternative is further supported by the geographical features of Pakistan in terms of highest received solar insolation in the world. Baluchistan province of Pakistan in particular has an average daily global insolation of 19–20 MJ/m^2 a day, so the need of the hour is to tap and invest in this alternative energy resource to overcome acute energy shortage [8].

The intermittent nature of renewable resources must be managed to ensure sustained power and the indigenous integration challenges to the existing power architecture must be properly examined. A review on planning of PV systems [9] and photovoltaic penetration issues in distribution networks are described in [10]. A description on country specific PV interconnection issues that includes effect of high penetration, system topology, type of the disturbance and the fault location is reported in [11]. PV generation units with reduced output current harmonics [12] and minimum loss operation of distribution networks are proposed elsewhere [13]. Comprehensive assessments on inverter architectures for various PV systems [14] and to extract maximum power using PV Arrays are available in the literature [15]. Similarly the effect of transients on bus voltage, system oscillations, and impact on the voltage profile for grid connected PV systems is elaborated in [16,17]. In [18], simulations have been performed for the analysis of IEEE 30-bus system. The results revealed that the PV power station can act as both PQ and PV node. In operational mode as PV node the PV plant generates reactive power to support the voltage of grid and this reactive power is a function of the rated capacity of PV plant. Correspondingly the decommissioning of conventional generators and induction of more PV based generation, system inertia and frequency regulation is reduced [19]. Furthermore there are power imbalances that create larger frequency excursion and high penetration of PV systems results in larger voltage recovery times. Such studies also include potential transient over-voltage issues coupled with PV solar generators [20]. To provide insight to dynamic behavior of the system under consideration operating at different operating points, stability margins equations of the combined multiple PV systems have also been reported [21]. The impact of PV solar generation on small signal stability of power system has been examined using modal analysis and time-domain simulations to resolve adverse effects of PV solar integration on stability [22].

To the best of author's knowledge, no economic/technical study has so far been reported for such mega scale PV installation in Pakistan. In this simulational analysis PV network integration and operational problems were investigated. The proposed study encompasses grid – 750 MW PV system interconnection issues in terms of load flow harmony, low and high frequency harmonics, voltage and frequency stability and increase in the short-circuit current level at the point of common coupling. The simulated case incorporates the entire power system of Pakistan with voltages ranging from 11 kV to 500 kV. The load flow analysis and maximum and minimum short circuit calculations were carried out to validate the throughput of PV system to the national grid of Pakistan. Since the location of this solar power park lies in Baluchistan, therefore day peak demand (1373.3 MW) of QESCO (Quetta Electric Supply Company) was used in the real time simulations. PV system power was collected at Kharan 132 kV bus and then stepped up using transformers of 220/132 kV having total transformation capacity of 750 MVA. Voltage of the buses was achieved within permissible range of $\pm$5% of nominal voltage levels and loading of transformers and lines fulfilled pre-defined contingency criteria.

2. Materials and methods

Pakistan's energy demand is exceedingly beyond the generation capacity and this gap between is widening due to increase in population, modern life style, transmission losses, electricity theft

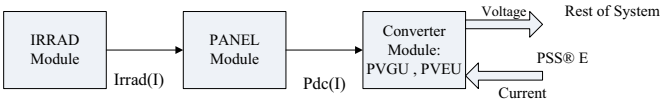

Fig. 1. PV dynamic model and connectivity scheme.

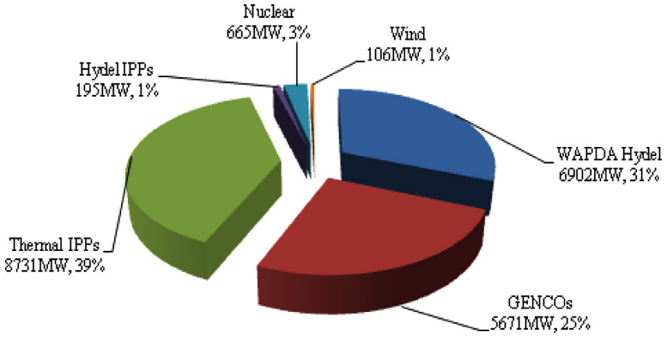

Fig. 2. Existing installed electricity generation capacity of Pakistan.

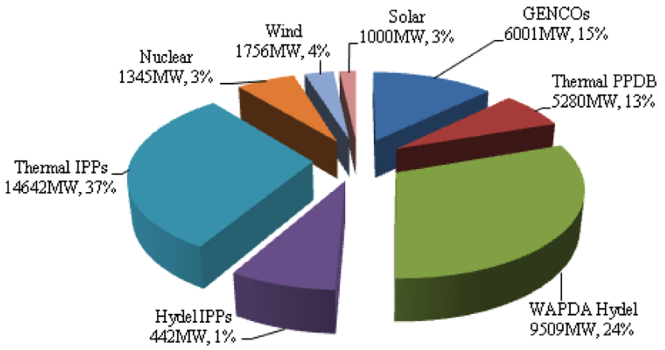

Fig. 3. Planned electricity generation capacity for the year 2017–18.