Analysis of Grid-connected Solar PV System Operation based on Energy Router Concept

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***Abstract*— The major limitation when using renewable energy resources is their inherent variability and dependence on climatic conditions. However, routing coordination of these resources with backup power can provide a reliable and economical electricity supply under different load demand conditions. This paper proposes the concept of routing in electrical networks to compensate for the energy deficit and manage the power transfer control in grid-connected and islanded modes. The coordination management of electrical energy resources in terms of active or reactive power is adopted using a routing matrix. A fuzzy approach is applied to realize the control mechanism from the routing topology perspective. The results show that the routing scheme meets the requirements of bidirectional power flow, where the balance of active power and the compensation of reactive power can be achieved.**

Keywords-- Energy router, active/reactive power, solar PV system, fuzzy routing matrix.

I. INTRODUCTION

The traditional power grid in many countries is facing many challenges (e.g. extreme weather events, security of energy supply issues, environmental constraints, uncertainty in fossil fuel supplies and the penetration of renewable resources). Recent collapses that occurred in some countries have raised concerns regarding the reliability of the systems, and the provision of continuous power supply to regions outside the fault zone during power outages. The blackout incidents in recent history highlighted the need for utilizing the reactive power capabilities of renewable energy converters to support the power grid during disturbances. Usually, when load demand is more reactive, the voltage begins to sag due to the large reactive power losses on transmission lines. The mitigation approach is to generate reactive power near the points of consumption. Solar photovoltaic (PV) systems are the most widely used renewable energy resources (RER). In this respect, distributed PV systems can be a handy and resilient source of reactive power, thus providing effective voltage regulation. Consequently, it is crucial to ensure that the existing operation of grid-integrated renewable energy generation meets the requirements of power grid codes, in terms of active power controllability, reactive power compensation, and fault ride-through capability. Although the draft and approval of grid codes can be varied from one utility to another, the transmission system operator is the responsible body for drafting codes that should go through a consultative process for endorsement from the system regulator (see Fig. 1) [1]. With the passage of time and advancements in technology, the inverter interface of PV has become more efficient and can be an economic source of reactive power compared to traditional reactive power compensation devices, like STATCOMs and capacitor banks. However, it is required to oversize the inverter by maximizing its apparent power to be larger than the maximum power output of the PV array. In this case, the excess capacity of PV systems is dispatched by the distribution utility to coordinate the voltage regulation [2]. Due to the unpredictable nature of grid-connected renewable energy systems, enhancing the stability of voltage during the fluctuations in renewable energy outputs is a crucial task, particularly in fault conditions. As the uncontrolled bidirectional power flow may impact the performance of protection system, an accurate formulation that takes into account the stochastic behavior of the system can help in designing the coordination control scheme of the power router. Additionally, implementing an intelligent model of electrical energy router that interacts with machine learning can mitigate the unnecessary operations of voltage regulators.

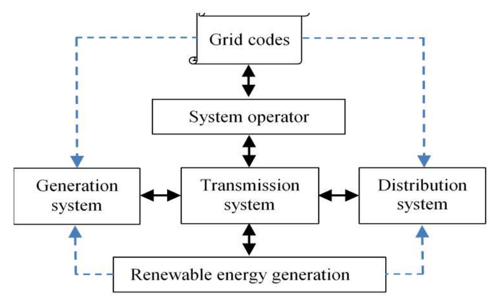

Figure 1. The basic structure of grid codes for grid-integrated renewables

II. ENERGY ROUTERS AND APPLICATION ASPECTS

The integration of power electronic devices with communication and automation systems is viewed as an energy router. It should meet the requirements of transmission latency, communication reliability, security of information, and accurate enforcement of intelligent management commands. In general, the functions of the energy routers can be categorized into user and grid levels. In decentralized power generation, the electricity consumers and distributed energy resources are

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