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Thyristor Switched Smart Transformer for Active Power Flow Control in Multi Micro grid System

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Abstract

An intentional active power flow control between microgrids in a multi micro grid system in the grid connected mode is achieved at the point of common coupling. The thyristor controlled on load tap changing transformer at the point of common coupling is equipped with voltage based power flow controller where different tapping are switched according to the required power flow condition to be satisfied and the amount of power to be transmitted. Accordingly, the voltage based droop control associated with the distributed generation units in each of the micro grid changes their active power generation. Thus, without much communication to other elements of the micro grids, the Smart Transformer at the point of common coupling allows active power exchange. The simulations performed in MATLAB/ SIMULINK for both three phase and single phase system follows that active power flow control is achieved in a multi micro grid system using the thyristor switched Smart Transformer. Hardware implementation has also been initiated to analyze the concept of power flow control with thyristor switched Smart Transformer and results are studied. The proposed system shows its operational effectiveness, which can be employed to solve grid emergencies in real time.

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Keywords: Distributed generation (DG)units; Low Voltage (LV) micro grid; Point of common coupling (PCC); Smart transformer(ST); Thyristor controlled on load tap changing transformer.

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1. Introduction

A micro grid consists of a group of distributed energy resources (DER) and interconnected loads with well-defined electrical boundaries that act as a single controllable entity with the capability of islanded and grid connected mode of operation capability. The DG units can either generate ac power or dc power. In case if dc power is generated, then power electronic interfaces are necessary to connect it with the micro grid. DG systems typically use renewable energy resources like hydro, biomass, biogas, solar power, wind power, geothermal power and increasingly play a vital role for the electric power distribution system. It has become vital to control the DG units and the power exchange between the micro grids so as to ensure a flexible and reliable micro grid operation. The introduction of more renewable resources to the micro grids has indeed made this task difficult.

The conventional transmission grid uses control strategies such as P/f droop or communication based schemes for the active power sharing of the DG units in a micro grid system. Taking account of the specific characteristics of a low voltage micro grid [1], an alternative control strategy based on the P/V droop could be initiated for the effective control of DG units. When the control using P/V droop is approached, the micro grid active power balance is achieved through the control strategy which modifies the RMS micro grid voltage at the inverter ac side as a function of the dc link voltage[2][3]. In case of any voltage limit violations, which will be determined by the constant power band and this control strategy is combined with the V_g/V_{dc} droop control [3]. The constant power band is determined by the specific characteristics of the generator and other DG units.

For the intentional control of the active power flow between the micro grid and the utility grid, the multi agent communication strategy is generally used. Using the secondary controllers and central controllers, the utility grid communicates the new set of reference power to be transferred to the recognized DG units [3]. But such a communication strategy cannot be used for the active power flow control when the P/V droop control and Vg/Vdc control strategy is used for active power generation control of the DG units as they operate in a distributed manner avoiding any inter unit communication. A possibility is thus, the on load tap changing transformer at the PCC can be used for the active power flow transfer, where the reference power to be transmitted between the micro grids is communicated only to the central controller at the transformer at the PCC thus making it a Smart Transformer[2].

In this paper the concept of the thyristor switched Smart Transformer is addressed where the active power flow between the utility and micro grid systems are controlled at the point of common coupling (PCC). This unit controls the active power exchange between the micro grids in the grid connected mode with and without the participation of the utility grid. To control the power flow, the ST equipped with thyristor control uses its taps that change the micro grid side voltage at the PCC. The thyristor control of the ST enables faster switching of the taps and avoids sparking problems as compared to normal OLTC transformer. Sections 2 and 3 discuss the characteristics of a low voltage micro grid and the concept of thyristor controlled Smart Transformer for the active power flow control in a multi micro grid system. Further, the simulation proof for a three phase system and single phase system are discussed. The hardware results were obtained for the active power flow between a single utility grid and micro grid using thyristor switched ST.

2. Active Power -Voltage Relation in Low Voltage Distribution System

The transmission lines can a low voltage, medium voltage and high voltage type. Given U_1 and U_2 are the sending and receiving end voltages respective and δ the load angle, the expressions for the active and reactive power flowing into a line is given by equations (1) and (2) respectively[4][7].

$$P = \frac{U_1}{R^2+X^2}[R(U_1 - U_2 cos\delta) + XU_2 sin\delta] \quad (1)$$

$$Q = \frac{U_1}{R^2+X^2}[-RU_2 sin\delta + X(U_1 - U_2 cos\delta)] \quad (2)$$

Comparing the typical line parameters of different transmission lines, it is inferred that the R/X ratio is highest for a low voltage micro grid [4].The resistance of a low voltage line is very much higher than the reactance value and hence the reactance can hence be neglected. Thus, a low voltage line becomes effectively resistive in nature and the expression for power angle δ and change in voltage ΔU becomes,