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MPSST Design for Power Flow Control in Hybrid System

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***Abstract*: Conventional power system includes four major sections, bulk generation, transmission network, distribution network, and loads. The main converter in the conventional electric grid is the low frequency passive transformer providing galvanic isolation and voltage regulation for various voltage zones. In this configuration, small-scale renewable energy resources are connected to the power system at low voltage zones or inside micro-grids. Nowadays the electrical main grid is managed in AC due to several reasons derived from the past. Recent years have experimented a rapid evolution of power electronic components able to dramatically enhance the effectiveness of the active and reactive power flow management. To investigate Community Energy Storage impacts on Volt-VAR Optimization (VVO) solutions for advanced distribution networks. It is one of the technologies employed to improve system stability, reliability and quality. This research introduces the application of the Multi-Port Solid State Transformer (MPSST) as an effective tool to support grid voltage at distribution level while integrating distributed energy resources. The solid state transformer replaces the conventional transformer between two voltage zones of distribution systems. Matlab/Simulink environment is used to simulate and test system with an MPSST. The simulation results prove the effectiveness of the MPSST supporting the distribution system at local level in a fast and efficient manner in response to disturbances caused by load variations.**

***Keywords*: MPSST, Micro Grids, Energy conversion, Renewable energy sources, Optimization.**

1. Introduction

In the existing power grid, the power flow is unidirectional, i.e., from the generating station to the user end. This structure of power grid is not going to serve the purpose in the near future, as the conventional energy sources will not be available. As a solution to this problem, people have started to include non-conventional energy sources in the existing grid in a distributed manner [2]. Therefore, the power flow in the grid needs to be bi-directional. At the point of penetration of renewable energy sources, the transformer is a must which will interlink the high voltage transmission line and low/medium voltage sources. The demand of transformers goes high with the number of distributed sources. It is very obvious that the line frequency transformers are heavy and bulky. Thus, the need of small and light weight transformers (solid state transformers) came into picture. Recent developments in the design of power electronic elements with higher voltage and power ratings and medium/high frequency enable making use of solid state transformer at different voltage levels in the distribution system and micro grid design. In this work, the concept of a Multi- Port Solid State Transformer (MPSST) for distribution network application is introduced. MPSST provides a compact, integrated and galvanically isolated multi-port node for micro grid and distribution applications and reduces the number and size of the converters in the concept of efficient smart distribution systems. Conventionally electricity grid structure includes power plants, transmission and distribution system, and AC loads. This nature of the power system is changing as the result of penetration of distributed energy resources, DC loads and smart components. Also, the whole power grid is moving toward the concept of smart grid which is a system with online monitoring and control and benefits from smart distribution and fault management. The future configuration of distribution system has discussed in several articles, and different configurations are suggested and studies for the future generation of distribution systems [2]. The impact of the concept of smart grid on distribution grid is investigated while the growing implementation of the DG in the grid for the case studies of Slovenia using statistical analysis and future prediction numbers. The common base in all of these designs and studies is having DER utilized in the power system. Higher efficiency, easier installation, and maintenance, survivability of the critical loads and better fault management are the main parameter in the different configurations which are improved in the different articles using software and hardware modification techniques. Due to the vast capability of the PE converters in interfacing between components and voltage zones in the power system, and the controllability advantages for the system, power electronic converters are considered as the enabler components for the promised smart and efficient future distribution systems. Also, one important requirement for connecting two voltage zones in any distribution system design is galvanic isolation between voltage zones. The transformer is the component which provides galvanic isolation in the available distribution by transferring power between two voltage zones through the electromagnetic field of the transformer without electrical connection. Solid state transformer includes a combination of power electronic converters and high or medium-frequency transformers. Having

SST in the distribution system, different voltage zones are galvanically isolated using the high-frequency transformer of the SST configuration which reduces the size and weight of the converter dramatically in comparison to the conventional transformers with the same voltage and power rating. Also, the power electronic stages of SST enable online monitoring of the system. There are two major factors which drive the research efforts on solid state transformers. The growing need for compact, controllable converters to utilize distributed energy resources within the electricity grid and the development of high power and high-frequency power electronic switches, which allows feeding the isolation transformer with very high frequency to optimize the size of converter. The introduced configuration in this study is a four-port SST which is capable of utilizing hybrid RER/ESS in a system with two zones of voltage using one compact converter:

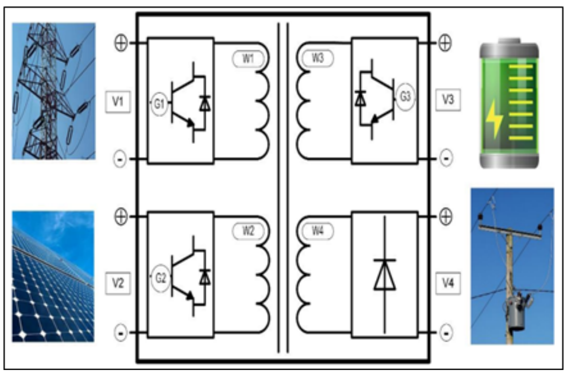

Fig. 1. MPSST applications for distribution system

MPSST [1] offers several adjustable ports for the components to connect and exchange power with each other. The MPSST comprises a multi-winding HF transformer to isolate the ports galvanically. Using MPSST enables higher efficiency and reliable centralized control for all of the connected components in the system.

2. SST architectures

The concept of solid state transformer in different forms has been studied by several articles since the early 80s. In this concept, a combination of power electronic converters and high or medium-frequency transformers form a controllable isolated converter.

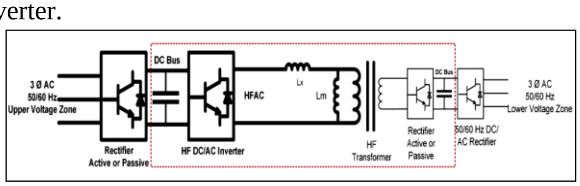

Fig. 2. AC-AC solid state configurations

Besides the normal functionalities of the conventional transformers [5] like galvanic isolation and voltage matching between two AC voltage zones, the power electronic based transformer benefits the power distribution system by enabling active monitoring and control on the voltage and current flow of the ports of the SST. Also, due to the medium or high-frequency design of the transformer of the SST, the size of the converter is smaller than the conventional LF isolated converters with the same voltage and power rating. This size and weight reduction which is enabled by involving power electronic converters to transfer power in high-frequency AC is the key motivation for designing high-frequency isolated power electronic converters. The relationship between transformer dimension and the characteristics of the core material and its nominal power can be calculated using equationThe red dot zone in Figure which includes two AC/DC converters and a transformer is the high-frequency section of the SST structure. These stages are common between all different SST configurations with DC bus bars. Based on the different applications of the SST, the configuration is extended with single or three phase low-frequency DC/AC converters to provide proper connection points for the grid or AC components. The rectifier stages of the SST could be active switch based rectifier which potentially makes the SST a bi-directional converter or passive diode bridge rectifier which allows the power to transfer only in one direction. SST offers several functionalities in a smart grid configuration including, protecting loads from power system disturbances, protecting power system from load disturbances, integrating energy storage systems (energy buffer), providing DC ports for distributed generation connection, and supporting voltage and power profiles [4]. Besides, SST can play an important role in realizing the DC/AC zonal power distribution system [7]. They will link the micro-grids to the MV transmission system as well as low voltage AC and low voltage DC systems. However, SST has some drawbacks in comparison to the regular transformers. First of all, the high-frequency switching in the SST converters increases the switching loss which affects negatively on the efficiency of the converter. Second, due to the higher number of components, the reliability of the converter reduces and also the converter control, especially for the grid application, would be very complicated. One solution to tackle the issue of high switching loss in the SST is using the resonant circuits to achieve ZVS [6] and ZCS. Having resonant circuit in the topology of the converter enables soft switching which ultimately improves the efficiency of the converter. Figure 2-2 shows a DC-DC SST with series load resonant (SLR) circuit included. The experimental tests on this configuration show the efficiency improvement from 92% to 96.5%.

3. MATLAB Simulink Model

The Simulink demonstrate in MATLAB gives a graphical UI, clients can call the standard library module from where the vital squares and segments are chosen and are appropriately associated with shape the dynamic framework show. There is a Dialog box for changing the properties of every individual segment utilized in the module and furthermore the framework parameters and in addition the setup parameters for the sort of reproduction wanted. For framework displaying, address parameters and numerical calculations are chosen we can begin the reproduction program Simulation of the framework. Degrees are utilized to get the yield waveform of voltages and current and workspace is likewise utilized for the equivalent.

4. Results

The proposed strategy is actualized utilizing MATLAB 2013b and tried for Distribution framework. Figure 4.1 Proposed Simulation Model of the System. In this framework, PWM terminating circuit is utilized to trigger the MOSFET Switches. 420 Volt Grid Connected to Inverter Circuit to examination the framework performance.

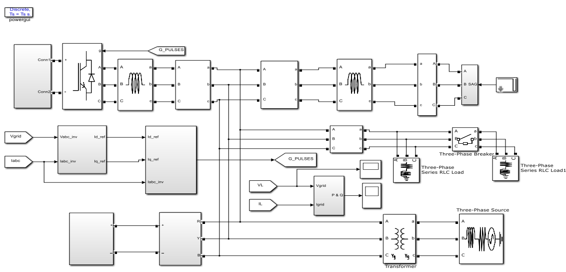

Fig. 3. Simulation model of proposed system

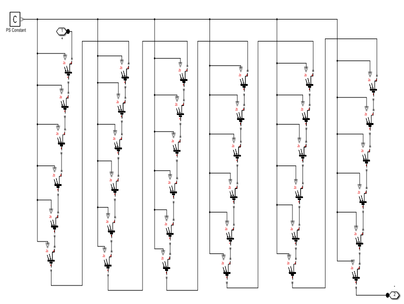

Fig. 4. Simulation Model of PV Module

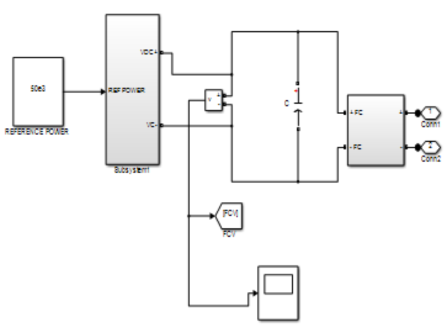

Fig. 5. Simulation model of fuel cell

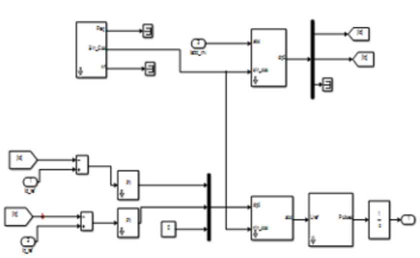

Fig. 6. Simulation Model of Firing Circuit for inverter circuit

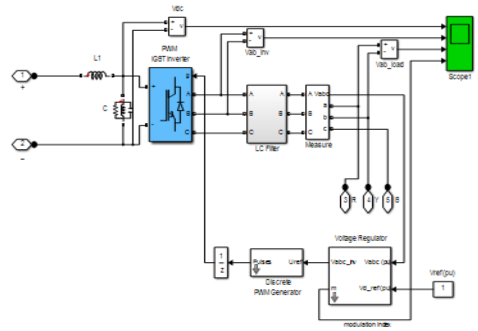

Fig. 7. Simulation Model of inverter circuit for PV Module

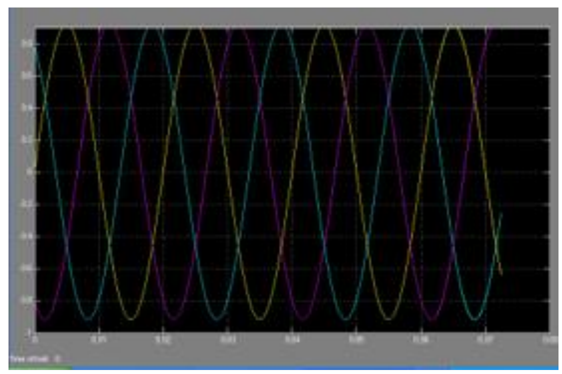

Fig. 8. Output voltage

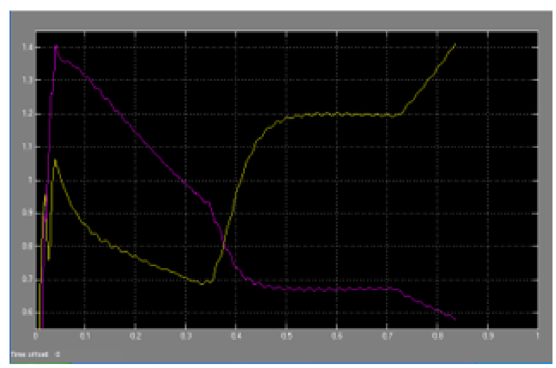

Fig. 9. Active and reactive power

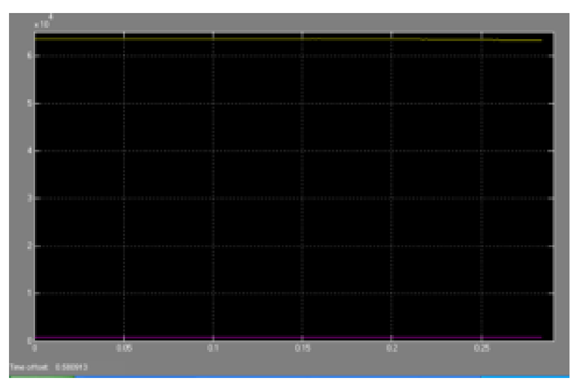

Fig. 10. Active and reactive power of load

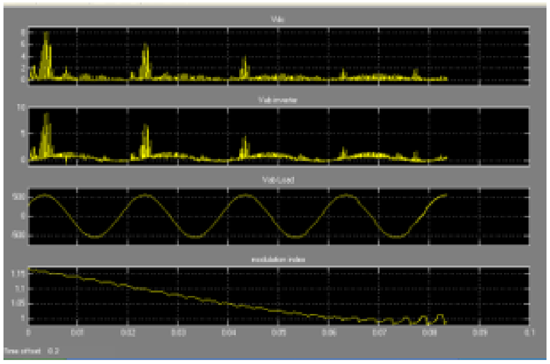
Fig. 11. Output of DC Voltage, Inverter Input

5. Conclusion

In conclusion a new architecture for an efficient PE converter-based distribution system has been suggested and Discussed in this paper. The main component of the new architecture is the MPSST which uses a multi-winding transformer. The paper discusses the advantages of MPSST as a new type of PE converter for microgrid application. The MPSST provides an isolated controllable multi-port node for the different elements including, DG, grid port, storage system and loads in a grid connected hybrid DG system which are sharing a same voltage level. Furthermore, the number of the conversion levels and controls in the system is optimized. Having this converter in the distribution network enables the implementation of semi-microgrids, including RERs, storage and DC or AC loads installed in all of the voltage zones of the system which increases the efficiency and survivability of the system in general since a portion of the generation is localized and also as the DC distribution is enabled. Also application of HF multi winding transformer in the MPSST minimizes the size and weight of the whole system dramatically.

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