Solid State Transformers for the Future Distribution Systems

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INTRODUCTION

- What is an SST?
  - Power Electronics Based Transformer
  - Use power electronics switches to chop 50/60 Hz into much higher frequency AC (e.g. 10's kHz)
  - Use power electronics to "re-make" and regulate the 50 Hz voltage

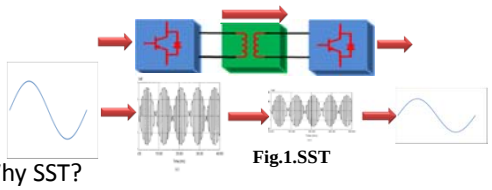

Fig.1.SST

- Why SST?

—Advantages?
Reduced size and weight
Decouple input from the output
Eliminate harmonic distortion
Improve voltage regulation
Control active and reactive power

—Disadvantages?
Efficiency
Reliability
Cost

Objective(s):

- ***Improve Reliability & Efficiency***
- **Investigate Potential Applications(High& Medium Power)**
- ***Add Extra Function(Imbalanced Loads Handling)***
- **SST Key Technology to Enable Future Smart Grid(See Fig.2)**

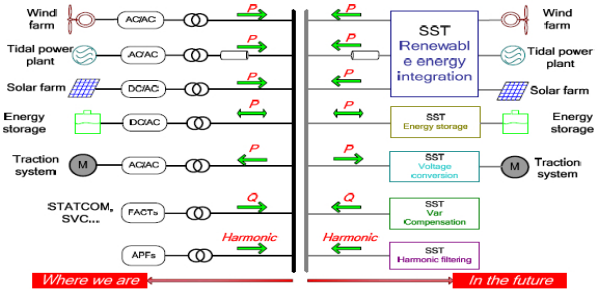

Fig.2. Potential Applications in the Future Distribution System

METHODOLOGY

- Comparison of two four-wire Solid State Transformers under Imbalanced Loads

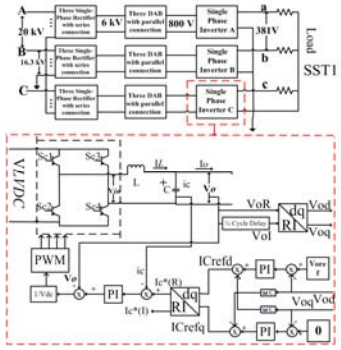

Fig.3.Overall three-Phase four-Wire SST (SST1)

Differences:

➢ **SST1**
The inverter stage consists of three single phase inverters.
The independent decoupled, control of the three phases

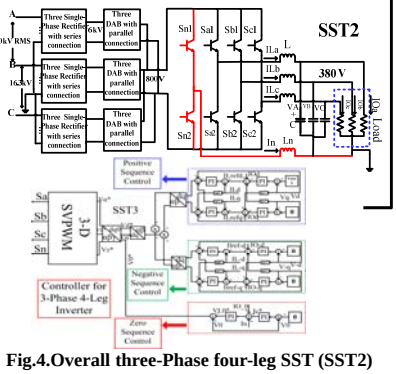

Fig.4.Overall three-Phase four-leg SST (SST2)

➢ **SST2**
The inverter stage with a three-phase four-leg inverter which uses a four-leg converter topology and ties the neutral point to the mid-point of the fourth neutral leg.

Positive, Negative and Zero-sequence components controlled ind

- Modular Design of Dual Active Bridge (DAB) DC-DC converter for a solid state transformer (SST)

➢ A DAB with n modules and m sub-modules will have n modules connected in an ISOP manner, with each of these modules further divided into m sub-modules in an IPOS manner.

ISOP- input series, output parallel connection
IPOS -input parallel, output series connection

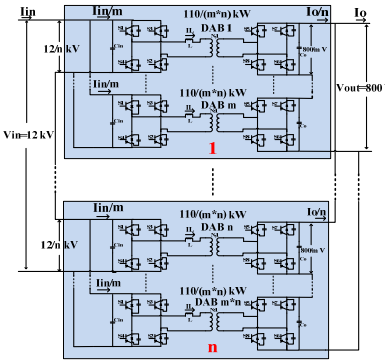

Fig.5. DAB Modularity

RESULTS

➢Results for Imbalance Loads Handling

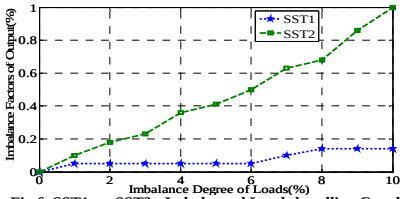

Fig.6. SST1 vs. SST2 : Imbalanced Loads handling Capability

Topology	Total Number of Switches	Balanced Loads		10% Imbalanced Loads	
		Total Loss (kW)	Power Efficiency (%)	Total Loss (kW)	Power Efficiency (%)
SST1	120	18.59	94.37	18.60	94.36
SST2	116	12.98	96.07	13.08	96.04

Table.7 Losses and Efficiency Comparison

➢ The Imbalance Factor of the Output for both SST1 and SST2 can be controlled to less than 1 %.

➢ Compared to SST1, which has similar capability to handle imbalance, SST2 has an overall 2% improvement in efficiency under both balanced and imbalance loads[1].

➢Results for Modularity Design

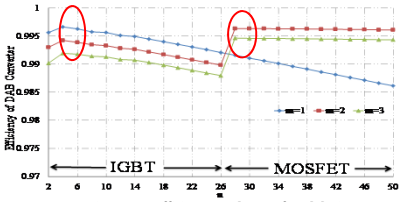

Fig.8. DAB Efficiency VS degree of modularity.

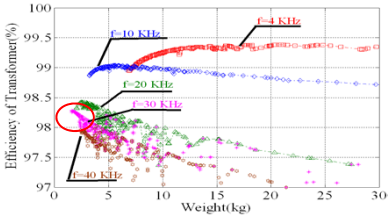

Fig.10.Weight vs. efficiency for single sub-module transformer with various frequency, n = 28, m = 2.

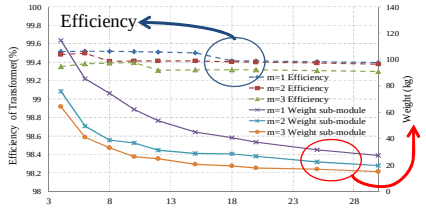

Fig.9. Sub-Transformer Efficiency &Weight VS degree of modularity.

➢ IGBTs as switches,
Optimum number of modules which maximize efficiency is usually low

➢ MOSFET with high frequency
A high level of modularization
Small efficiency penalty
Significant potential for transformer size reduction
Limitation of size reduction--The temperature rise constraint

Table.2 Comparison of overall DAB efficiency and weight achievable for two different levels of modularization

# Modules	4	56
Frequency	4 kHz	30 kHz
Switches	IGBT	MOSFET
DAB Efficiency	99.6%	99.6%
Maximum transformer Efficiency	99.5%	98.3%
Overall Efficiency	**99.1 %**	**97.9 %**
Transformer Weight	**100 kg**	**2 kg**
Total Weight of all transformers	**400 kg**	**112 kg**

CONCLUSIONS

- **SST can be an excellent system for ensuring distribution level feeder voltage balance in the face of significant loads imbalance**
- **SST2 is the best performing SST topology and has the best trade-off between cost, performance and efficiency for imbalance and fault scenarios. Drawback – slow response.**
- **For medium frequency, high modularity degree DAB with MOSFET, an almost four-fold reduction in total weight of transformers can be achieved for a decrease in efficiency of 1.2%[2].**

REFERENCES

[1] T. Yang, R. Meere, O. Feely, T. O'Donnell, "Performance of 3-Phase 4-Wire Solid State Transformer under Imbalanced Loads."_2014 IEEE PES T&D Conference and Exposition, Chicago, Apr.2014.
[2] T. Yang, C. O'Loughlin , R. Meere, T. O'Donnell, N. Wang, Z. Pavlovic, "Investigation of Modularity in DC-DC Converters for Solid State Transformers." 2014 IEEE 5th International Symposium on Power Electronics for Distributed Generation Systems (PEDG), Galway, Jun. 2014.

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