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Integration of Renewable Energy Resources into a Power Electronic Power System

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Abstract: ***The use of renewable energy sources (RES) has increased exponentially during the present years. Even though the energy production through the renewable sources had increased, they are unable to integrate it into the utility power grid directly. This happens due to the frequency instability and other differences which are existing between the utility power grid and that of micro grids (WECS or SPV). If we are able to integrate the renewable sources to the utility grid, the overall power production will be large and thus the increased energy demand can be easily met. Here in this paper we are discussing about the possibility of integration of different renewable energy resources to the utility grid with the help of a power electronic transformer in combination with a variable frequency converter and also the methods to solve the existing frequency instability in the utility power system.***

Keywords: Power electronic transformer, utility grid, renewable resources, frequency converter, frequency instability

1. Introduction

The conventional power generating systems are unable to meet the energy demand since the demand for electrical energy is increasing day by day. In such a scenario, sources other than traditional are to be used to meet the excess demand of energy. Due to the same, the use of renewable energy sources (RES) has increased exponentially in these years. Even though the energy production through the renewable sources has increased, they are unable to integrate it to the utility power grid directly. This happens due to the frequency instability and differences which is existing between the utility power grid and that of micro grids. If we are able to integrate the renewable sources to the utility grid the overall power production will be large and thus the energy demand can be easily met.

Here in this paper we are discussing about the possibility of integration of different renewable energy resources, RES; to the utility grid with the help of a power electronic transformer in combination with a variable frequency converter and also the method to solve the existing frequency instability in the utility power system. Power electronic transformers are basically a multiple winding high frequency transformer which can integrate multiple number of renewable resources to the power grid. To match the frequency of power produced with that of the grid, we are incorporating a variable frequency converter on the grid side. To solve the frequency instability problem, in this paper we are discussing about mainly three methods viz acceleration response, inertia emulsion and damping enhancement.

2. Topology

Power electronic transformers are an inevitable part of a power electronics power system. A simplified power electronic power system contains the renewable energy sources [RES], storage devices and as well as the corresponding loads. Examples for a power electronic power system are micro grids and smart grids. Power electronic transformers are considered as the heart of a power electronic power system and it is basically a multilevel high frequency converter combined with AC-DC converters on both side.

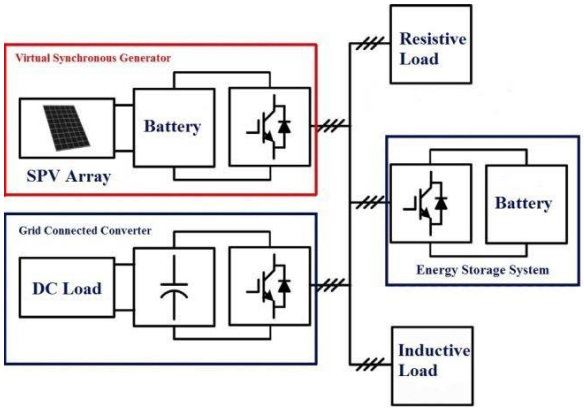

Figure 1: Power electronic power system

While considering integrating the renewable energy recourses to the power grid efficiently, we are using a high frequency transformer and a converter preferably a cycloconverter on the grid side.

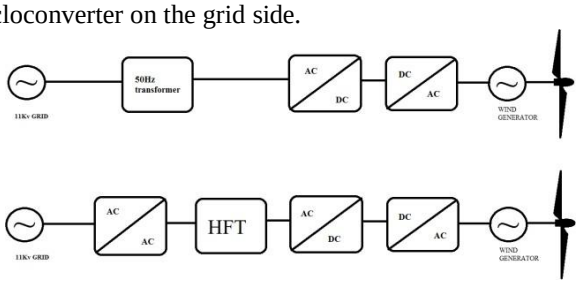

Figure 2: (Top) conventional WECS (bottom) with power electronics transformer on grid side.

Figure 2 shows the difference between a conventional integration of wind energy conversion system and the proposed model of wind energy conversion system.

In this system we are using a multi winding high frequency transformer [HFT] connected with a single phase

cycloconverter on the grid side to integrate the resources. The multi winding high frequency transformer can connect multiple numbers of resources and connect them all to a single grid. This is a major advantage of the system since we only require a single transformer for the whole conversion. Each of the resources, both WECS and SPV, are connecter to the multi winding high frequency transformer through a series of rectifier and inverter otherwise by a AC-DC converter and a DC-AC converter and also a DC-DC converter for the solar photovoltaic array. A general block diagram for the proposed method of power integration to the grid is given in Figure 3, power electronic transformer is also termed as multi winding high frequency transformer.

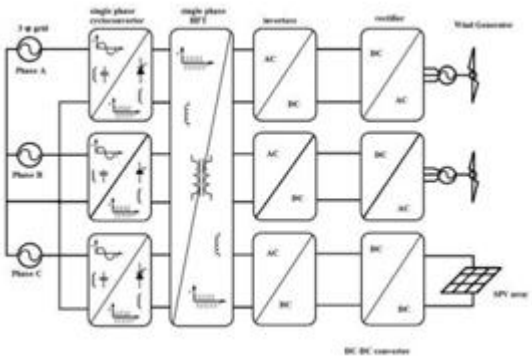

Figure 3: Simplified block diagram of PET

- The proposed methods have single phase cycloconverter on the grid side, connected to each of the 3 phases on the grid. The cycloconverter used is a thyristor based converter, since the thyristors can handle high amount of current than any switching devices,

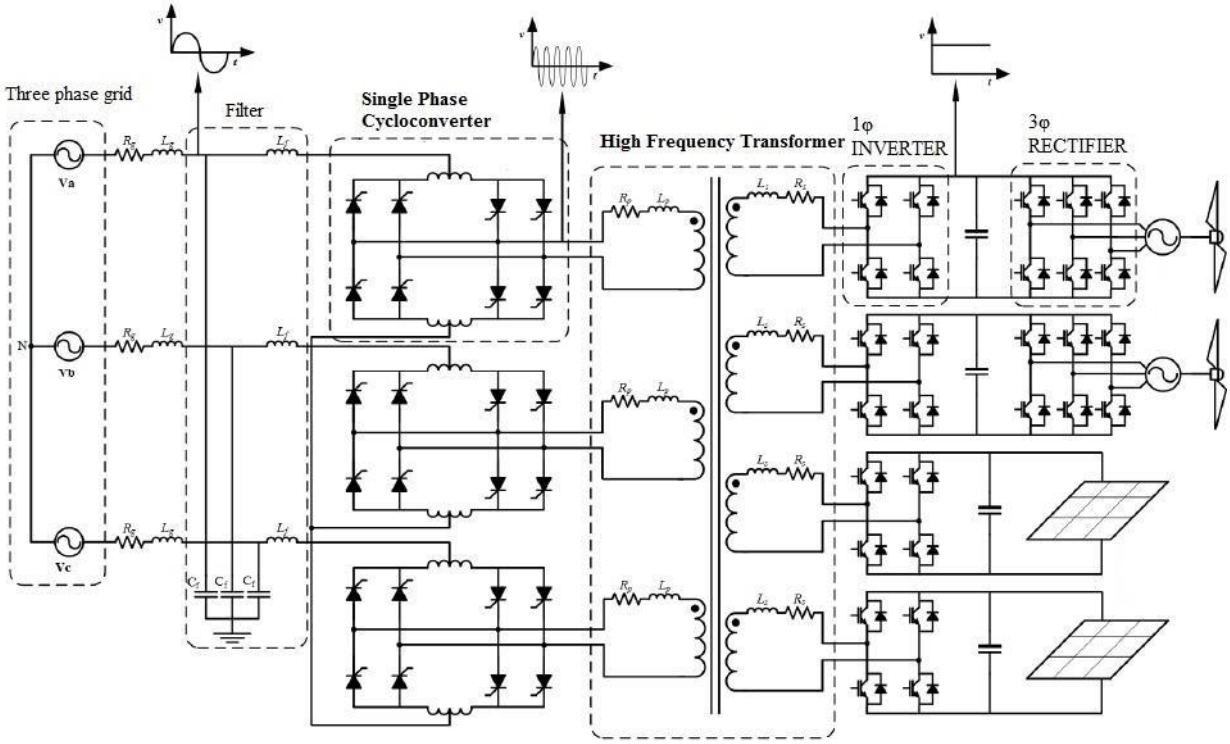

Figure 4: Detailed diagram of power integration to grid

- The power quality issues that could arise in such a scenario like Harmonics can be suppressed as the cycloconverter works on continues current circulation mode of operation.
- The stabile frequency conversion is attained in a single stage thus resulting in less loss in the system.
- The three of the primary winding of the high frequency transformer is connected to the cycloconverter, while the multiple windings of the secondary side connect a number of sources.
- The transformer leakage inductance acts as a low pass filter for ensuring continues current flow which can also result in the proper commutation of the thyristors.

From *Figure 4*, the renewable energy sources (wind energy conversion system and solar photovoltaic array) are connected to H-bridge converters which are in turn connected to the single phase multi winding high frequency transformer. A converter is required in this situation to maintain the quality of the power produced. While the wecs require both rectifier and inverter, the spv array only require the inverter section alone. Both the inverter and rectifiers make use of IGBT since they are havigh high switching frequency as well as are able to self commutate.

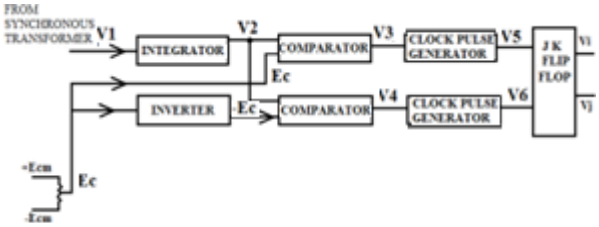

Figure 5: Cosine firing scheme

The single phase cycloconverters use thyristors since it is able to carry high current.

- The firings of the thyristors in the cycloconverters are done by using the cosine scheme factor of triggering (*Figure 5*).
- This scheme is used such that the amplitude of the voltage at the output, as well as the frequency can be controlled along with the phase control.
- The cycloconverter works in continues current mode of operation since it is an advantage of not causing any crossover distortion.
- Therefore the output of the cycloconverter operating in a circulating current mode will have only a low amount of harmonics present.

Stability Improvement

While discussing about the integration of the RES to the grid, the other auxiliary equipments which plays a major role in the process are also to be considered. If their proper working is not ensured, the whole integration process will not happen smoothly. The whole power generation and transmission systems are housed in a power station. Conventional Power stations are very sensitive to variations in the system frequency and if the frequency deviates from the normal value, it might be overloaded. The auxiliary electric motors in the generation system deliver air and fuel and other requirements (such as water and coolant) to the entire power generation systems.

If low speed occurs due to variation in the frequency of the system, it will significantly affect these auxiliary electric motors. This phenomenon will lead to several cascading shutdowns of the power stations. The frequencies below 47 Hz will lead to damage of steam turbines, while hydro power plants and thermal units are more robust. Frequencies down to 45 Hz, may face the worst, which is disconnection.

In order to avoid such a situation which may lead to the disconnection, there should be stability in the frequency of the generated power. Stability improvement of frequency can be done by the following methods. Damping Enhancement, Inertia Emulation and Response Acceleration.

3. Conclusion

Integration of renewable sources, to the grid with the help of a power electronic transformer in combination with a variable frequency converter on the grid side is proposed here. The method to solve the existing frequency instability in the utility power system is also discussed. Power electronic transformers can integrate multiple number of renewable sources to the power grid. To match the frequency of power produced with that of the grid, we are incorporating a cycloconverter on the grid side. To solve the frequency instability problem, in this paper we are discussed about mainly three methods viz acceleration response, inertia emulsion and damping enhancement.

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