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ULTIMATE GRID POWER FLOW CONTROL USING FLEXIBLE POWER ELECTRONIC TRANSFORMER

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Abstract:-The rate of the transported electrical energy within the lines of the power system is referred to as 'Power Flow' to be more specific, it is the active and reactive power that flows in the transmission lines. Distributed Generation (DG) takes place at small and medium power generators that are connected to the distribution side of the power system. Many DG units are based on renewable energy sources such as solar and wind. Introducing a number of generators on the distribution side leads to big changes of the power flow in networks. First, the direction of the power flow is different from the traditional direction. When DG units in one area feed loads in other areas, there will be reverse power flow from the distribution to the transmission side. Second, the output energy of renewable sources depends on weather conditions. With the increasing percentage of renewable energy sources in use, a large amount of power has to be controlled to enable the power system to quickly switch between the renewable sources and stand-by power generation. Therefore, stand-by power, which can be provided by near-by power plants or energy storages, should be available when renewable energy is insufficient to supply the load. This leads to an increased need for power flow control methods.

To enable the trading of electricity between different zones, power systems in different locations are inter-connected. During an emergency, the inter-connection can reroute power to support the loads, thereby increasing the stability of the system. However, inter-area connections result in multiple parallel paths between power plants and consumers, which give rise to loop flow and cause congestions. To reduce the loop flow, there is a need for bidirectional power flow control between zones. The electricity market is a system for effecting the purchase and sale of electricity, using supply and demand to set the price. With the emerging liberalization of the electricity market, power prefers to flow 'from the source with the lowest price in the direction of the highest price'. To ensure that the power flows according to the economic law, rather than Ohm's law, the power should be controlled to flow within the transmission network with the desired direction and quantity. A smart grid is a concept that integrates IT technology into the electricity network to control appliances at consumer locations to save energy, reduce cost, increase reliability and transparency. The idea of a smart grid is to monitor conditions anywhere in the power generation, transmission, distribution and demand chain. Any change in conditions, in the environment, in the power supply market, locally in the distribution grid or at home, will be reported to the system central controller to change the power flows accordingly.

key words: Power Electronic Transformer (PET), micro grid,

I. Review of Power Flow Controlling Devices

Power flow is controlled by adjusting the parameters of a system, such as voltage magnitude, line impedance and transmission angle. The device that attempts to vary system parameters to control the power flow can be described as a Power Flow Controlling Device (PFCD). Depending on how devices are connected in systems, PFCDs can be divided into shunt devices, series devices, and combined devices (both in shunt and series with the system), as shown in Fig. 1.1

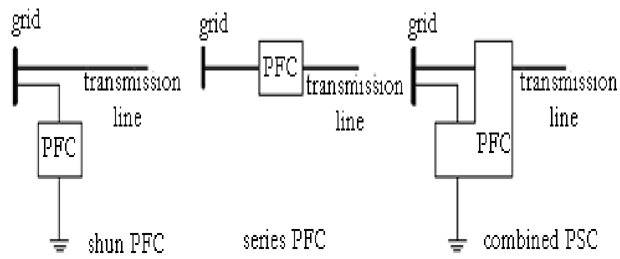

Fig. 1.1: Simplified diagram of shunt series

A shunt device is a device that connects between the grid and the ground. Shunt devices generate or absorb reactive power at the point of connection thereby controlling the voltage magnitude. Because the bus voltage magnitude can only be varied within certain limits, controlling the power flow in this way is limited and shunt devices mainly serve other purposes. For example, the voltage support provided by a shunt device at the midpoint of a long transmission line can boost the power transmission capacity. Another application of shunt devices is to provide reactive power locally, thereby reducing unwanted reactive power flow through the line and reducing network losses. Also, consumer-side shunt devices can improve power quality, especially during large demand fluctuations.

A device that is connected in series with the transmission line is referred to as a ‘series device’. Series devices influence the impedance of transmission lines. The principle is to change (reduce or increase) the line impedance by inserting a reactor or capacitor. To compensate for the inductive voltage drop, a capacitor can be inserted in the line to reduce the line impedance. By increasing the inductive impedance of the line, series devices are also used to limit the current flowing through certain lines to prevent overheating.

A combined device is a two-port device that is connected to the grid, both as a shunt and in a series, to enable active power exchange between the shunt and series parts. Combined devices are suitable for power flow control because they can simultaneously vary multiple system parameters, such as the transmission angle, the bus voltage magnitude and the line impedance. Based on the implemented technology, PFCDs can be categorized into mechanical-based devices and power electronics (PE)-based devices.

II. POWER ELECTRONIC TRANSFORMER

In electric power distribution system, transformers perform several functions, such as voltage transformation, isolation, noise decoupling etc. The conventional distribution transformers operate at low frequencies (50Hz) making them bulky and expensive. A power electronic transformer (PET) operates at much higher frequencies, of the range of several kHz. The transformer size, which is inversely proportional to the frequency and saturation flux density, could be reduced under high frequency operation conditions. The PET utilizes power electronic converters along with a high-frequency transformer to obtain overall size and cost advantages. The PET substitutes the conventional 50 Hz transformer at the PCC of a micro-grid, connecting the later with the utility. This results in an enhanced power management for the micro-grid as well as decentralized control of the DERs and controllable loads within the micro-grid. A dynamic control of active and reactive power flow from the utility is possible. It also allows a bi-directional flow of active power between the utility and the micro-grid. Also a smooth transition from grid-connected to isolated mode of micro-grid is possible.

III. Flexible Power Electronic Transformer (FPET)

In recent years, significant advances in power semiconductor device technology, low-cost, high-speed control processors, and matured PWM algorithms have led to a number of modern power converter topologies. A new type of transformers based on Power Electronics PE has been introduced, which realizes voltage transformation, galvanic isolation, and power quality enhancements in a single device. The PE based transformer provides a fundamentally different and more complete approach in transformer design by using power electronics on the primary and secondary sides of the transformer. Several integrated PQ features such as instantaneous voltage regulation under load dynamics

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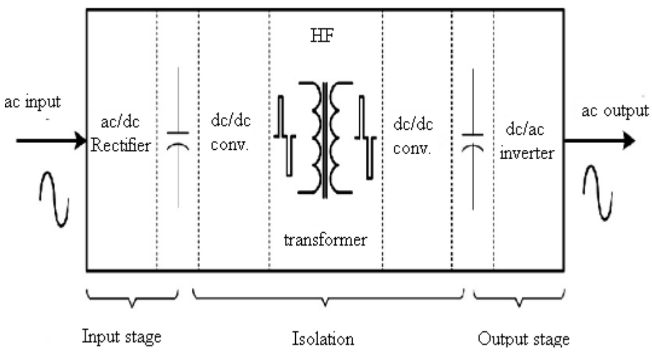
and transients, voltage sag compensation, power factor correction, and harmonic suppression can be incorporated into PET.

The PET can compensate both the active and reactive powers, and remove the power quality disturbances such as sag, swell, under voltage, over voltage and voltage flicker. In comparison to the conventional transformers, it has low weight, compact volume, extended functionality, and eliminates the necessity for toxic dielectric coolants. The PE-based transformer is a multi-cellular step-down converter that can directly connect to medium voltage levels on the primary side and provide a low voltage, highly stable interface for consumer applications. PET replaces conventional transformers and performs better voltage regulation.

IV. Principle of operation



The line side AC waveform is modulated with a static converter to a high-frequency square-wave and passed through a HF transformer and again with a synchronous converter, it is demodulated to AC form. Since the transformer size is inversely proportional to the frequency, the high frequency transformer will be much smaller than the line frequency transformer. So, the transformer size and weight are reduced noticeably. This scheme can be utilized to mitigate power-line disturbances such as voltage sags and swells in low voltage equipments.

Mathematical relation between transformer size and frequency

The transformer equation, $E = 4.44\ f\ B\ N\ A$………………………………………… (1)

Where, E is the voltage in the winding either primary or secondary,

f is the frequency,

B is the flux density in the core,

N are the number of turns on the winding, and

A is the cross sectional area of the core.

Power devices are operated at magnetic saturation so B is constant, hence it is clear that at higher frequencies the number of winding turns N is reduced.

V. BENEFITS OF POWER ELECTRONIC TRANSFORMER

- Restricted active power flow to the micro-grid, at a desired value determined by the main utility grid.
- Utilization of the change in local grid frequency, to dynamically control the active power generation or consumption within the micro-grid..
- Ensures decentralized control of the DERs as well as the controllable loads that operate synchronously to supply to the demand within the micro grid.
- Provides smooth transition from islanding to grid-dependent mode without the need of grid synchronization
- At PCC because of the three-stage topology and the unique capabilities of each stage of PET, the total stress factor is much lower than it would be for the ac/ac chopper.
- At PCC Unlike some solid-state transformer designs, magnetic isolation is achieved between the primary and secondary.
- The output voltage of PET is sinusoidal regardless of the input power quality or the output current wave shape.

- Bi-directional active-power flow capability at the PCC.
- Voltage regulation by control of reactive power.
- Extra degree of freedom due to the presence of active-power controller in a possible deregulation and market strategy within the micro-grid.

VI. ADVANTAGES OF PET

Active and reactive powers compensation: The power actually consumed in

I. An ac circuit is called active power (VI cosφ). The lagging reactive power is responsible for the low power factor (VI sinφ). Main disadvantages of reactive power are:
   a. KVA rating of the equipment. Electrical machinery is always rated in KVA.
   b. Increase in electricity bill.
   c. Losses increases.
   d. Decrease in power factor, there by penalty in electricity bill.

II. Devices such as shunt, series, synchronous condenser, DVR, UPQC are widely employed for reactive power compensation. A weak network is very sensitive to load changes. A sudden change in active load will cause both a phase jump and a magnitude fluctuation in the bus voltage, whereas reactive load changes mainly affect the voltage magnitude. With the addition of energy storage to a static synchronous compensator (STATCOM), it is possible to compensate for the active power change as well as providing reactive power support. The PET can compensate both the active and reactive powers.

III. Flexible regulation of the voltage and power: Regulation means the change in secondary terminal voltage from no load to full load at any particular load (about 4%). On the consumer point it should be as minimum as possible.

IV. Remove the power quality disturbances such as sag, under voltage, over voltage and voltage flicker

V. Compact: low weight, compact volume.

VI. Eliminates the necessity for toxic dielectric coolants: Mineral oil, beta oil, silicone are widely used coolant materials, cost of coolant higher and its replacement also difficult.

VII. Conclusion

Thus by using power electronics transformer as a power flow devices in microgrid power system active & reactive power control ,power factor control, power quality can be improved. Simultaneously by using power electronics circuits conventional transformer size & weight will get reduced.

The losses due to high frequency operation at transformer core and winding can be reduced by replacing the ferromagnetic material of core by nanocrystalline magnetic material which is for achieving higher density and copper material of winding by cable or Litz wire.

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