Anelementalanalysis on dynamic stability in a micro-grid system during compensations with impedance based analysis

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Abstract: *Various aspects of instability in a micro-grid system were analysed in this paper. To maintain the optimum power flow in the system various control and compensation techniques were implemented in the micro-grid system. These techniques may induce small changes in the power system parameters. All the compensation and control techniques implied in the system should not result in large changes in system behaviour. In distributed generation mostly wind turbines would supply the major part of the grid. Induction generators in wind turbines will induce large reactive power in micro-grid which would definitely need to be compensated. To improve the power quality in the system, filters were designed which might cause dynamic transients in the system. A detailed analysis of dynamic instability in the micro-grid system was analysed and a diagnostic algorithmic approach for improving the stability in the grid was proposed in the paper.*

Introduction: Fossil fuels were primarily used to generate electricity. The products of combustion of such fuels were CO_2, CO, NO, NO_2, SO_2 etc. A large source of pollution would be collected in the atmosphere as a result it might lead to environmental degradation. Use of renewable energy might be the better choice for this case. Various micro-grid systems were designed with the optimal use of renewable energy resources like wind, solar, geothermal and magneto hydro dynamic power generation etc. Most of the micro-grid have wind and solar as their major resource.

Common Issues in micro-grid system:

i. Generation control issue:

The main objectives of generation control were

(i) To hold the system frequency at or very close to the specified nominal value for various loading conditions.

(ii) To maintain correct value of power interchange between control areas.

(iii) To maintain each unit's generation at an economical value.

Once the load change has occurred, the supplementary control must act to restore the system frequency to the nominal value. This is done by adding an integral control over the control areas.

In the micro grid system the frequency variation in one control area depends on the power electronic converter units employed to switch the supply at nominal frequency despite the governor control in the normal grid system. Almost frequency compensation is done for wind turbine supplied micro-grids where power electronic switching was more expensive.

The Area Control Error (ACE) from various interconnected micro-grids was collected and a separate frequency correction techniques will be adopted for individual turbine units.

The dynamic response of the turbine follows the oscillations of the form

$$(s+\propto)^2 + \omega^2 -\propto^2$$

ii.**Common Power Frequency disturbances**:The term power frequency disturbance describes events that are slower and longer lasting compared to electrical transients. The effects of power frequency disturbance vary from one piece of equipment to another and with age of the equipment. Old equipmentis subjected to harmful disturbances over a prolonged period. One of the most common power frequency disturbances in a micro-grid system is voltage sag. Voltage sags are typically due to starting on large loads such as electric motor or an arc furnace. Induction motors draw starting current ranging between 600 to 800 % of their nominal full load current. Therefore depending on the instant at which voltage is applied to the motor, the current can be highly asymmetrical.

Various techniques were followed to minimize the power frequency disturbances like voltage regulators, static uninterruptible power source system (UPS), rotatory uninterruptible power source system to maintain the voltage within the steady state tolerance (not ranging above 10% of nominal voltage). A proper stability control can be adoptable for these types of power frequency disturbances by sensing the voltage variations in the micro grid system dynamically within the stability range.

iii. Electrical Transients:

They are the sub cycle disturbance in AC waveform. In a micro-grid system power electronic switching is most common factor. Switching transients may occur in some abnormal cases which may be severe to the connected utilities. Apart from the switching transients, atmospheric phenomena can also produce transients due to lightning, solar flares and geomagnetic disturbances.

More transients will persist in the micro-grids during the time of fault current interruption, switching of power lines and capacitor banks for reactive power compensations.

iv. Reactive power compensation:

Series compensation: In series compensation, the FACTSsare connected in series with the power system. It works as a controllable voltage source. Series inductance exists in all AC transmission lines. On long lines, when a large current flows, this causes a large voltage drop. To compensate, series capacitors are connected, decreasing the effect of the inductance.

Shunt compensation: In shunt compensation, power system is connected in shunt (parallel) with the FACTS. It works as a controllable current source. Shunt compensation is of two types:

Shunt capacitive compensation: This method is used to improve the power factor. Whenever an inductive load is connected to the transmission line, power factor lags because of lagging load current. To compensate, a shunt capacitor is connected which draws current leading the source voltage. The net result is improvement in power factor.

Shunt inductive compensation: This method is used either when charging the transmission line, or, when there is very low load at the receiving end. Due to very low, or no load – very low current flows through the transmission line Shunt capacitance in the transmission line causes voltage amplification (Ferranti effect). The receiving end voltage may become double the sending end voltage (generally in case of very long transmission lines). To compensate, shunt inductors are connected across the transmission line.

Synchronous condensers:

The synchronous condenser is a synchronous machine running without a prime mover or a mechanical load. By controlling the field excitation, it can be made to either generate or absorb reactive power. With a voltage regulator, it can automatically adjust the reactive power output to maintain constant terminal voltage. It draws a small amount of active power from the power system to supply losses.

Static VArcompensators(SVC): They are shunt connected devices to control the reactive power in a power system. There are different types of SVC that can be implied for reactive power absorption and injection. Several applications of SVC are, they prevent voltage collapse, enhance the damping in system oscillations, controlling of temporary over voltages and transient stability enhancement etc.

D-STATCOM:A voltage-source converter (VSC) with PWM provides a faster control that is required for flicker mitigation purpose. A PWM operated VSC utilizing IGBTs and connected in shunt is normally referred to as "STATCOM" or "DSTATCOM". A shunt-connected synchronous machine has some similarities with the STATCOM, but does not contain power electronics. The capability of the synchronous machine to supply large reactive currents enables this system to lift the voltage by 60%. D-STATCOM has the same structure as that of an STATCOM.

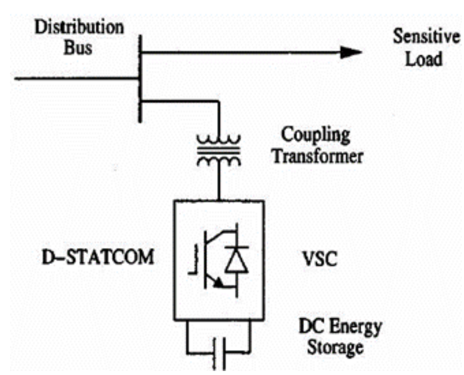

Fig.1. D-STATCOM connection

v. Harmonics:

Periodic waveforms other than the fundamental frequency are called as harmonics. In a micro grid system harmonics have a great impact due to implementation of more switching operations using power electronic devices. Use of nonlinear devices in the power system may give rice to harmonics in the entire system. Voltage and current distortions are produced in the system due to harmonics which results in instability in the grid system. Even loads that are linear will generate nonlinear currents if the supply voltage waveform is significantly distorted.

In order to mitigate the harmonics in the system, Harmonic filters are designed which is classified into passive and active filters. Use of inductance and capacitance of appropriate value which can be tuned to the harmonic frequency to be filtered will act as passive filters. In active filter design, the distorted current is sampled using power electronic devices, draws a current from a source of such magnitude, frequency composition and phase shift to cancel the harmonics in the load. Active filters can respond to changing in load, harmonic condition, whereas passive filter are fixed in their harmonic response.

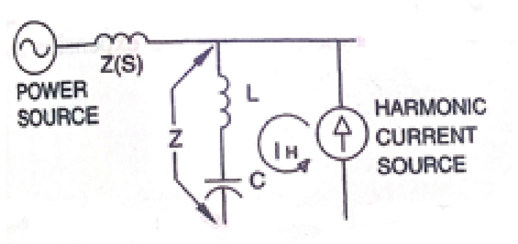

Fig.2.Passive filter design

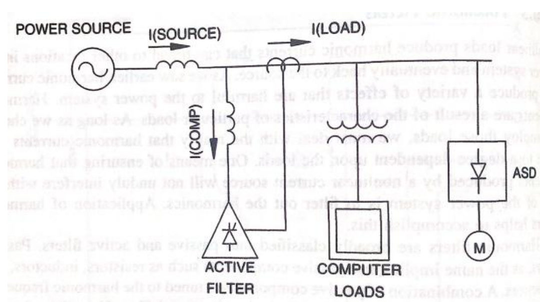

Fig.3.Active filter design

Method of stability compensation:

The stability control is partitioned into two broad classifications.

i. System level control: It charecterize the energy balance between generation and demand, Load management over the entire micro grid, Energy efficiency (quality of electricity), communication with other devices etc.

ii. Local control: It denotes the power balance between the control areas.

An impedance based approach may be followed to analyze the stability of a micro-grid system.

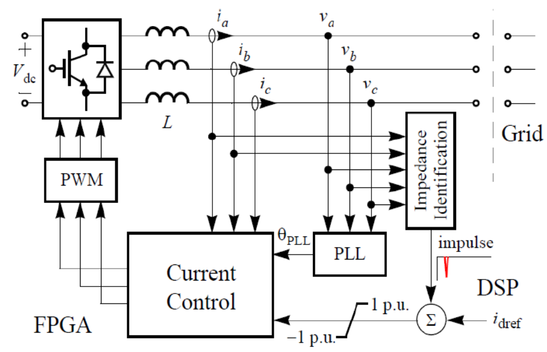

Fig.4.Impedance measurement in micro-grid system

The change in impedance (in terms of voltage and current) in the system is taken as the parameter for stability compensation. When there is any fault in a system either voltage or current in the grid is being changed which alters the impedance of the grid system (by taking the ratio of voltage and current). A proportional current impulse injection control is given to the grid corresponding to the change in impedance.

The reduced equivalent circuit model was given below.

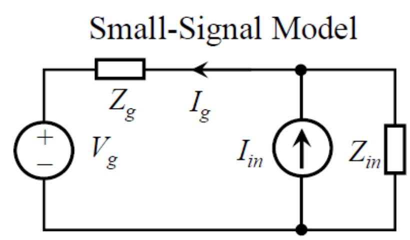

Fig.5. Reduced system model

$$\frac{I_g(s)}{I_{in}(s)} = \frac{Z_{in}(s)}{Z_{in}(s)+Z_g(s)} = \frac{1}{1+\frac{Z_g(s)}{Z_{in}(s)}}$$

The system will be in stability if Z_g/Z_{in} meets the Nyquest stability criterion

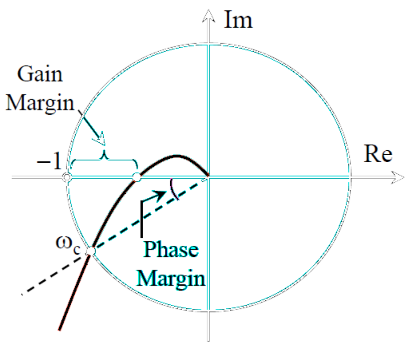

Fig.6.Nyquest Stability criterion

Conclusion:

The stability in micro-grid system is certainly needs to be maintained for stable operation. Here various compensation techniques were analysed in the micro-grid system which are required to maintain the optimal power flow in the system are definitely need to be in the stability limit during their compensation action. An impedance based algorithm for sensing the stability in the system with impulse current injection control technique for compensation was spotlighted in this paper.

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