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Steady State Operation and Control of Power Distribution System In Distributed Generation

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Abstract: In this research paper presents the voltage control methods with distributed generation and impact of DG on power distribution system. In this paper DG as a Wind Turbine (DFIG) and issues involving in connecting DG with power distribution system.

Keywords: Distributed Generation, Doubly-Fed Induction Generator

I. INTRODUCTION

Distributed resources (DR) or distributed generators (DG) connected to the distribution systems provides a different type of possibilities for energy conversion and generation compared to large generators connected to the transmission system. For various renewable energy resources like wind turbines, small and micro size wind turbines, conventional diesel generators, internal combustion generators, gas-fired turbines, PV cells and energy storage technologies, converters are required to provide electricity from these resources Despite the different categories of these distributed resources, the behaviour of a DR mainly depends upon the type of the converter that is connected with these DR in order to interact with the Electrical power system (EPS). These electrical converters are classified into three major types, depending on the type of DR with which are connected like synchronous generators, asynchronous (or induction) generators, and static (or electronic) inverters. The rotating generators like synchronous and asynchronous generators can be driven by wind turbines, water turbines, steam turbines, internal combustion engines, combustion turbines or electric motors. The static inverters can be supplied by dc storage sources (such as batteries), by dc generating sources (such as fuel cells), or by an AC generating source and a converter (such as a high- or variable-speed combustion or wind turbine). These machines respond differently to changes because of their different mechanical and electrical inertias and the time constants of the regulators by which they are controlled. Steady-state voltages in distribution networks cab controlled in several ways. Capacitor bank and line voltage regulator, which are mostly used in MV networks. On the other hand, off-load tap changer on distribution transformer can be used to adjust the voltage at the LV side. One of voltage control objectives is to keep the voltage at the customer within a suitable range during normal operation. The voltage range for normal operation is defined in different standards. IEEE Std. 1159-1995 and CENELEC EN 50160 indicate + 10% voltage variation (from the nominal voltage) as normal operating Voltage. The Swedish Standard SS 421-18-11 indicates +6%/-10% voltage variations as normal operating voltage. Voltage control equipment were designed and operated based on a planned centralized generation and on the assumption that the current always flows from the substation to the MV system, and then to LV customers; and that the voltage decreases towards the end of the feeder. The introduction of DG makes this assumption no longer valid. DG generally will increase voltage at its connection point, which may cause overvoltage during low load conditions .The effect of a single DG on the voltage profile of a LV distribution feeder was analysed , by assuming that the line reactance is negligible. However, the reactance of overhead (OH) lines in a LV feeder is in the same order as the resistance. This indicates that the reactance should not be neglected. When the contribution of DG power is high; DG may cause either the voltage to exceed maximum allowed voltage Interest in Distributed Generation (DG) in power system networks has been growing rapidly. This increase can be explained by factors such as environmental concerns, the restructuring of electricity businesses, and the development of technologies for small-scale power generation. DG units are typically connected so as to work in parallel with the utility grid; however, with the increased penetration level of these units and the advancements in unit's control techniques, there is a great possibility for these units to be operated in an autonomous mode known as a micro grid. Integrating DG units into distribution systems can have an impact on different practices such as voltage profile, power flow, power quality, stability, reliability, and protection. The impact of the DG units on stability problem can be further classified into three issues: voltage stability, angle stability, and frequency stability. As both angle and frequency stability are not often seen in distribution systems, voltage stability is considered to be the most significant in such systems.

II. ISSUES OF DG CONNECTED WITH ELECTRIC POWER SYSTEM

A-Equipment Ratings

The rated current of the lines must not be exceeded. Under standard voltage levels and power factor conditions the rated current of the line can be translated directly into a rated Active power for that line. There is also the constraint of the transformer rating, where the amount of generation connected minus the minimum load must not exceed the transformer rating.

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B-Short Circuit Level (SCL)

The magnitude of the transient voltage drop experienced at the buses in a network is an indication of the strength of the system. In this manner the SCL is a measure of the strength or robustness of a system . The SCL of a system refers to the current that results when there is a fault on the system. Generators, depending on the type of electrical machine employed, may contribute to the SCL. An increase in the SCL is generally favorable as it will increase the strength of the system. Although it must be ensured that the short circuit level does not exceed the rating of breakers and other equipment and this poses a hazard to the safe operation of the network. A maximum short circuit rating for all equipment is laid down

C- Short Circuit Ratio (SCR)

The short circuit ratio is the ratio of generator power to the short circuit level It gives an indication of the voltage dip experienced near the generation in the event of a feeder outage. The connection of induction generators to high impedance circuits may lead to voltage instability problems if the SCR is not kept within acceptable limits. The dip in wind farm terminal voltage that results from a fault leads to an acceleration of the induction generator, leading to over speed. If the speed is increased to a level above the critical value, the generator will accelerate out of control. This may lead to voltage collapse as the induction generator absorbs more reactive power. If the short circuit level is large enough, the transient voltage dip will be limited and the system will remain stable.

D- **Voltage Rise**

If DG is connected to a network section, it will alter the active and reactive flows and hence change the voltage dropped along the lines. It has been shown that DG leads. Distributed Generation to a significant voltage rise at the end of the long, high impedance lines. A rise in voltage occurs if there is low demand and high generation, which leads to a large amount of power flow along lightly loaded lines with high impedance. This problem is particularly acute in rural areas, where demand tends to be low. In addition, the resistive element of the lines on distribution systems is higher than other lines.

E- Losses

Losses are an important consideration when designing and planning the distribution system. Losses are inevitable on any network; however, the amount can vary considerably depending on the design of the network. With the introduction of distributed generation, the network is being utilized in a different way with more variable and bidirectional power flows. The level of losses is closely linked to the power flows. Losses area functions of the square of the current, i.e. a doubling in current results in losses being quadrupled. Therefore the allocation of DG and the altered power flows that result may have a significant impact on losses and may provide an opportunity to ameliorate them.

F- Power Quality

DG can have a considerable impact on power quality within the distribution system. Voltage flicker refers to dynamic variations in the system voltage. It can be an issue with wind power, given the variable nature of its energy source. However, the development of more sophisticated turbines has reduced the severity of flicker, due to the increased filtering effect of the generators. Some forms of DG may employ power electronic converters to interface with the system. This can alter the harmonic impedance of the system and care must be taken at the design and planning stage. In particular, there is the potential for resonances between capacitors or cables, which may ha detrimental effect on the operation of the generator. There are standards which dictate the acceptable levels of each of these quantities, which must be adhered to DG also has the potential to improve the power quality, through its contribution to the short circuit level.

G- Reliability

Reliability has always been an important issue for system planners and operators Reliability can be measured by the indices of SAIFI (System Average Interruption Frequency Index) and SAIDI (System Average Interruption Duration Index), which measure the average frequency and duration of supply interruptions respectively.

III. METHOD OF VOLTAGE CONTROL IN POWER DESTRIBUTION SYSTEM

The following equation represents the voltage variation V across the line

$$\Delta V = \frac{PR + QX}{V} \quad \text{----} \quad (1)$$

Where, V represents voltage variation, P and Q represent Active and reactive power output of DG respectively, X and R are reactance and resistance of the line connecting with DG, V is nominal voltage of DG terminal. A radial feeder connected with a DG is shown in Fig. An on-load tap changer (OLTC) transformer, a local load, a reactive power compensator, automatic voltage controllers (AVCs), a line drop compensator (LDC) and a energy storage device are also connected on the network.

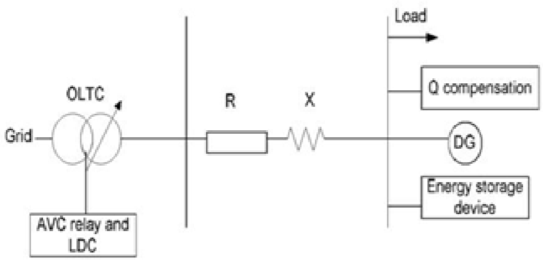


Fig 1 Radial feeder with connected DG

X/R ratio is compared with transmission line relatively low in a distribution network. According to above equation Significant amount of power injected by DG will result in voltage rise/drop on the distribution network, especially in a weak distribution feeder with high impedance. The voltage variation would also depend on several factors including DG size and location, and method of voltage regulation However, since the local generation units are generally owned and managed independently of each other, there is little or no coordination of the local generators with the centralized Distribution system controls. The objectives of managing the local units (maximization of efficiency and profitability of the local system) could be to some extent conflicting with those of the distributor (system losses minimization or voltage support optimization).In the presence of DG, generation and load patterns exhibit variability in time and space, leading to various operating conditions, whose range of variation cannot be simply synthesized on the basis of reference cases with maximum and minimum loading levels. Moreover, the output from some DG sources (such as wind and photovoltaic systems) depends on random parameters, making it necessary to extend the tools used for evaluating the voltage profiles to the use of probabilistic power flow calculation techniques.

A- On-load Tap Changers (OLTCs)

The on-load tap-changing transformer (OLTC), or voltage regulator, is an essential part of a distribution network. Automatically adjustable OLTCs are commonly used at distribution substations to raise the starting voltage for a feeder under load, so that some point along the feeder has a desired voltage. The adjustment is proportional to the load, so this practice works well for all anticipated loading conditions. This control strategy is referred to as the "line drop compensation." The amount of permissible voltage increase is limited if there is a load (customer) near the voltage regulator, so in some cases additionVoltage regulators, or OLTCs, are typically constructed as autotransformers with automatically adjusting taps. The controls measure the voltage and load current, estimate the voltage at the remote (controlled voltage) point, and trigger the tap change when the estimated voltage is out of bounds. Multiple tap change actions may be performed until the voltage is brought within bounds. The taps typically provide a range of ±10% of transformer rated voltage with 32 steps. Each step of voltage is therefore 0.625% of the rated voltage.2 al voltage regulators along the feeder run might be necessary. OLTC control the voltage in distribution Network which maintain a stable secondary voltage by selecting the appropriate tap position. It is an effective way to control the voltage by shifting phase angle and adjusting voltage magnitude. It is usually in conjunction with AVC relay and LDC. The AVC relay continuously monitors the output voltage from the transformer; a tap change command will be initiated when the voltage is above the pre-set limits. The LDC used to compensate additional voltage drop on the line between the transformer and load location, particularly, in the far end of the feeder. An intentional time delay, normally within 30 to 60 seconds, is always implemented in OLTCs so as to avoid unnecessary tap change operations during the transient voltage fluctuations. The tap change operation usually takes 3−10 minutes to move from one position to another, and a several minute time interval between frequent operations is also required with considering the oxidation of tank oil. Coordination between DG outputs and OLTC tap controls is a necessity in order to allow higher DG integration. Otherwise, power injection levels can be severely limited if substation voltage is kept constant by the OLTC transformer.

B- Power Factor-Voltage Control

Distribution network operators have traditionally required all DGs that are connected to the distribution network to Operate in power factor control (PFC) mode. The advantage of PFC is that it is less disruptive to the network devices such as OLTCs. However, the disadvantage of this method depends on a certain limit of generation connected to the system, whereby, a further increase in the generation will still result in voltage rise. The Power Factor Control – Voltage Control (PFC-VC) method combines the behavior of the generator's operation in two modes namely, constant power factor and voltage control. At normal conditions where the measured voltage is within the statutory upper and lower limits, the generator will operate in constant PFC mode. However, at times when the voltage deviates above or below the statutory limits, the generator will adopt the VC mode, that is, by varying the excitation of the automatic voltage regulator. In the PFC mode, the real power over reactive power ratio is kept constant, with the reactive power following the variation of real power. In the VC mode, the automatic voltage controller is activated to vary excitation and move the operating point within the bus voltage limit. This method is implemented with the knowledge of combining the advantages of automatic voltage regulator and PFC and is also termed as automatic voltage/power factor control. Independent producers adopt PFC strategy as a means to avoid penalties due to excessive reactive power consumption. In the method is by increasing the input of generation to the distribution system while maintaining a fixed unity power factor operation. Other methods of voltage rise mitigation are combined with this PFC to tackle the voltage rise problem. In three different modes of power factor operations is adopted by generators which is unitary, capacitive or inductive power factor depending on the regulatory operating rules. An adaptive PFC presented in proved to be able to increase the generation capacity. This method is part of an active management scheme which has been implemented for maximizing wind power generation.

IV. SIMULATION MODEL OF DG CONNECTED WITH ELECTRIC POWER SUSTEM

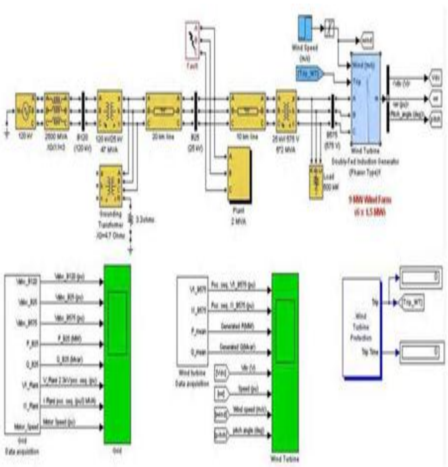
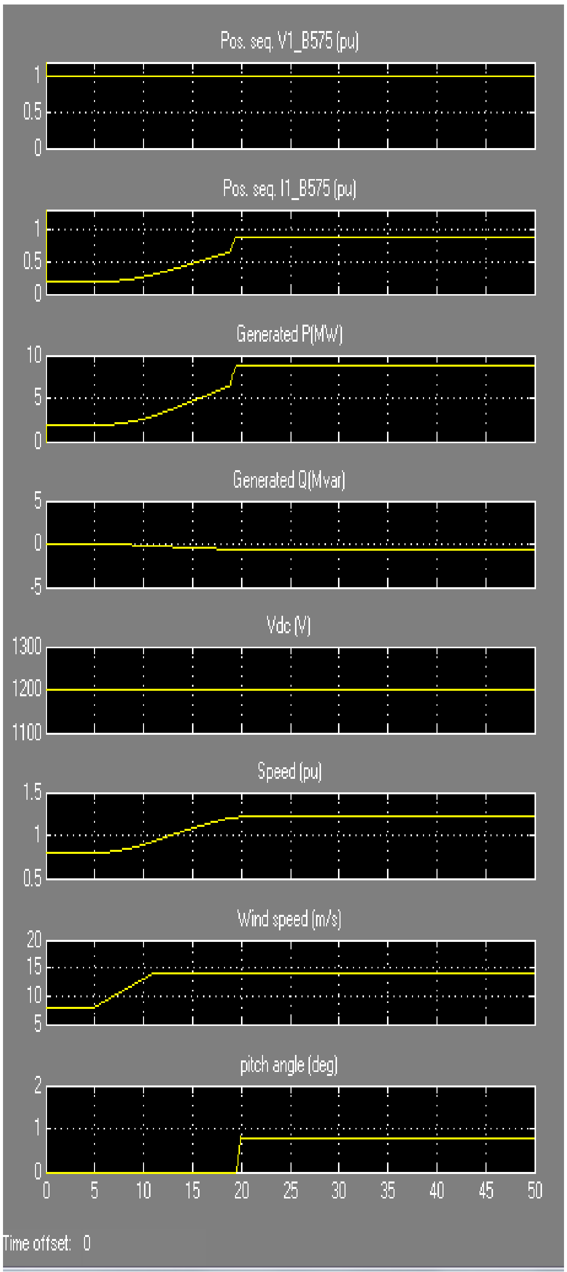


Fig Doubly-Fed Induction Generator (DFIG) Driven by a Wind Turbine model

SIMULATION RESULTS

A 9-MW wind farm consisting of six 1.5 MW wind turbines connected to a 25-kV distribution system exports power to a 120-kV grid through a 30-km, 25-kV feeder. 2300V, 2MVA plant consisting of a motor load (1.68 MW induction motor at 0.93 PF) and of a 200-kW resistive load is connected on the same feeder at bus B25. Both the wind turbine and the motor load have a protection system monitoring voltage, current and Machine speed. The DC link voltage of the DFIG is also monitored. A -Fed Induction Generator (DFIG) Driven by a Wind Turbine model is shown on figure



CONCLUSION

This research paper show that the voltage controls and impact on Power Distribution System with Distributed Generation (DG). The goal has been to develop a simulation method that gives a sufficiently detailed picture of the electric power system and Steady state conditions to enable accurate steady state calculations, but which still keeps simulation time reasonably short.

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