INDUCTION GENERATORS FOR SMALL SCALE ELECTRIC POWER GENERATION

by S. Karunaratne & B.S.P. Perera

Use of the normal induction machine as a generator has received much attention over the past few years. It is capable of working as a generator while connected to a power system consisting of other generators or as a stand alone generator. Whichever the case is, the magnetising or exciting current has to be supplied to the induction machine. In the former case, this lagging reactive power can be supplied to the induction generator by the rest of the power system or can be locally generated using a bank of capacitors, whereas in the latter case, the bank of capacitors connected across the machine terminals will always be required. In this case the build-up of machine terminal voltage will depend on the remnant magnetism present in the rotor, the speed of the prime mover and the amount of capacitance connected.

In the case of the induction generator connected to a three-phase power supply, the rotor is driven above the synchronous speed, in the correct direction. If the excitation is not provided locally by way of capacitors, some reactive power is drawn from the supply while active power is supplied to the system. If the excitation is provided entirely locally, then the machine will supply active power to the system without drawing reactive power from the system. The amount of active power will naturally be controlled by the speed of the prime mover.

The induction generator offers certain advantages over the conventional synchronous generator. These include the reduced plant cost, absence of d.c. excitation, brushless rotor (in the case of squirrel cage machine), robustness and simple construction and reduced maintenance. Further, in the case of a short circuit across the machine terminals, the fault current contributed by the machine is limited as the excitation voltage itself reduces rapidly.

Due to the requirement of reactive power and the inability of controlling the terminal voltage, induction generators of only small capacities are more common, where the rest of the power system takes care of the voltage and the reactive power requirements. The supply and control of reactive power is not at all a difficult problem at present, with the availability of static reactive power sources. Preliminary studies have shown that induction generators can even exclusively be the source of power generation on a large scale, incorporating thyristor controlled static reactive power sources (1). Undoubtedly, it is also possible to have hybrid generation where both induction generators and synchronous generators are used.

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With the recent emphasis on energy management, the use of non-conventional energy sources, such as bio-gas, wind energy and gasifiers, have become increasingly popular. Industrial co-generation too has been given high priority. Small-scale rural electricity generation will be particularly useful in developing countries. In all these situations, the induction generator is a potential competitor, owing to its many advantages over the conventional synchronous generator.

This presentation highlights some important fundamental aspects on the selection, general operational aspects and protection of induction generators. Further details are available in the bibliography cited here.

Selection of a Suitable Machine

The provision of reactive power from the system for the induction generator poses no problem as similar magnitudes of reactive power are drawn by induction motors without any problem. Reactive power, if necessary, can be provided locally with static capacitors. Hence the capacity of the induction generator is not a limiting factor, provided the prime mover has adequate capacity to match the generator.

The voltage rating of the machine must obviously match the system voltage. There is no basis for selecting an induction machine with a higher terminal voltage rating than the system voltage, as the induction generator will be equivalent to an under-excited synchronous generator where the internal voltage is less than the terminal voltage. This is in contradiction to the view expressed by Nailen (3)

General Operational Aspects

To connect an induction generator to the existing power supply, it is brought up to a speed near synchronous speed and then, the circuit breaker is closed. Obviously, if there are no capacitors connected across the machine terminals, there will be no out of phase closure as there is no terminal voltage on the machine. Hence the closing of the circuit breaker does not amount to synchronisation. However, if the capacitors were connected across the machine terminals the machine would have already built-up its own voltage. Then the conventional synchronisation procedure adopted in the case of the synchronous generator should be followed. Whatever the case may be, the resulting transient is not significant. For unexcited (with no capacitors), Induction Generators, on connecting to the busbars at Synchronous Speed, Nailen (3) says "Tests show that for even the largest size machines upto 15000 hp, the resulting transient does not exceed 150 percent of the idle or magnetising current". One of the worst possible cases is the closure of the circuit breaker while the machine is at standstill. Then it will start as a motor taking the usual large starting current, accelerating the prime mover too. Interlocking arrangements can be made to avoid such situations. If synchronisation is to be avoided, then the capacitors can be kept connected on the supply side of the circuit breaker, so that there is no possibility of a machine terminal voltage, when the circuit breaker is open. However, having the capacitors in the above fashion must ensure that no undue voltage is caused on the busbars prior to the connection of the induction generator. Alternatively, thyristor controlled static reactive power sources can be used at the induction generator terminals, which are usually controlled in a closed loop manner.

Protection

There are quite a few aspects to be considered on protection. It is emphasised here that the degree of protection will depend on the nature of the scheme in which the induction generator or generators are used. Some of the typical problems encountered and possible solutions are presented here.

There is a possibility of a high over voltage due to excessive excitation if an induction generator gets disconnected from the 3-phase supply while the capacitors are connected across the generator terminals, and precautions must be taken. As mentioned earlier, by having the capacitors connected on the busbar side of the machine circuit breaker, the above situation can be avoided. However, if the 3-phase open circuit is at a distant end, there is a possibility of an over voltage at the machine terminals. A possible solution is the use of an over voltage relay which will shut down the prime mover or disconnect the capacitors. If a controlled reactive power source is available, the automatic adjustment of the delay angle of the thyristors will also take care of the voltage. Another possibility is to make sure by arranging the induction generator reactive power requirement to be shared by both capacitors and the mains. It has to be ensured that the capacitors alone will provide just enough reactive power to raise the machine terminal voltage only to a safe value, under open circuit conditions.

If an electrically disconnected induction generator is re-closed there is a possibility of an out-of phase reclosure resulting in a large disturbance. This is not only a problem associated with the induction generators, but also can be present with an induction motor fitted with p.f. correcting capacitors, driving a high inertia load which will maintain the speed. The auto reclosures, if used, must therefore be fitted with a phase angle sensing device which will not allow out-of phase reclosure.

In contrast to the synchronous generator which will feed a short circuit across the terminals, the induction generator, with loss of excitation voltage, will not feed the fault. Protection will have to be applied elsewhere in the system. However, the induction generator can be provided with necessary short circuit protection if required.

Depending on the situation, the induction generator may be provided with a reverse power relay to stop it from motoring.

Single-phasing is another problem which may appear in practice when one phase is lost, and the generation will continue because of the presence of the prime mover. The current can become unbalanced like in the case of an induction motor. Phase failure protective devices used in the case of motors can also be used to protect the generator in such cases.

It can be summarised that the use of the induction generator does not give rise to serious problems. The problems are somewhat similar to what one encounters with an induction motor. Depending on the situation in which induction generators are used, suitable protection should, of course be applied.

Conclusion

Considering all aspects, it is concluded that the induction generator will prove to be a good alternative in small scale electric power generation.

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Note from the Editor

The Deputy General Manager, Transmission and Generation Planning of the Ceylon Electricity Board is of the view that small generators whether synchronous or induction should not be connected to the CEB system at present, though there is no objection to their use in independent and segregated systems - as in estates.