Synchronous reactance of an alternator represents

Synchronous Reactance and Vector Diagrams of a Loaded Alternator For the same field excitation, terminal voltage is decreased from its no-load value E0 to V (for a lagging power factor). This is because of 1. drop due to armature resistance, IRa 2. drop due to leakage reactance, IXL 3. drop due to armature reaction. The drop in voltage due to armature reaction may be accounted for by assumiung the presence of a fictitious reactance Xa in the armature winding. The value of Xa is such that IXa represents the voltage drop due to armature reaction. The leakage reactance XL (or XP) and the armature reactance Xa may be combined to give synchronous reactance XS. Hence XS =XL Xa Therefore, total voltage drop in an alternator under load is = IRa jIXS = I(Ra jXS) = IZS where ZS is known as synchronous impedance of the armature, the word 'synchronous' being used merely as an indication that it refers to the working conditions. Hence, we learn that the vector difference between no-load voltage E0 and terminal voltage V is equal to IZS, as shown in Fig. 37.26. Vector Diagrams of a Loaded Alternator Before discussing the diagrams, following symbols should be clearly kept in mind. E0 = No-load e.m.f. represents the maximum value of the induced e.m.f. E = Load induced e.m.f. It is the induced e.m.f. after allowing for armature reaction. E is vectorially less than E0 by IXa. Sometimes, it is written as Ea. In Fig. 37.27 (a) is shown the case for unity p.f., in Fig. 37.27 (b) for lagging p.f. and in Fig. 37.27 (c) for leading p.f. All these diagrams apply to one phase of a 3-phase machine. Diagrams for the other phases can also be drawn similarly. Also Read Similar Questions Below : ⇒ The self induced emf in the coil undergoing commutation is called thereactance voltagestatically induced voltage.dynamically induced voltagenone of the above.⇒ If rated dc voltage is applied instead of ac to the primary of a transformersecondary of transformer will burn.primary of transformer will burn.secondary voltage will be excessively high.there will be no secondary voltage.⇒ Generally the no-load losses of an electrical machine is represented in its equivalent circuit by aparallel resistance with a low value.series resistance with a low value.parallel resistance with a high value.series resistance with a high value⇒ In an induction motor, if the air gap is increasedspeed will reduce.efficiency will improvepower factor will he loweredbreakdown torque will reduce⇒ A slip-ring induction motor is recommended for applications requiringhigh starting torquevariable speed operation.frequent starting, stopping and reversing operations.all of the above features.⇒ Which of the following motors is suitable for timing and control purposes?Reluctance motorSeries motorRepulsion motorHysteresis motor⇒ The synchronous impedance of a synchronous-induction motor is much larger than that of a synchronous motor due toits larger air gap.presence of damper bars in it.its less magnetic reluctance.supply of dc excitation to its 3-phase rotor.⇒ Armature reaction mmf and leakage reactance of a synchronous machine are determined byopen-circuit and short-circuit tests.open-circuit and zero pf tests.open-circuit test only.zero pf test only.⇒ For speeds higher than say 3000 rpm, the machine used isinduction motor.synchronous motor.universal motor.none of the above.⇒ The 5th space harmonics in the mmf developed by balanced fundamental frequency armature currents rotate at ____ times the synchronous speed with respect to the field.5/66/55/45/7⇒ In a series RLC circuit at resonance, the magnitude of voltage developed across the capacitoris always zero.can never be greater than the input voltage.can be greater than the inpu voltage however, it is 90° out of phase with the input voltage.can be greater than the input voltage and is in phase with the input voltage.⇒ The kVA rating of an isolation transformer increases when connected as an auto-transformer due toestablishment of conductive link between the primary and secondary.rise in secondary terminal voltage.increase in secondary current.reduced copper losses.⇒ When a ceiling fan using a capacitor run motor is switched on, it hums but does not run. When it is driven by some external means it runs in the direction in which it was made to run. The probable cause isopen-circuited capacitorblown fusesshort-circuited capacitorany of the above⇒ A 220 V shunt motor develops a torque of 54 Nm at an armature current of 10 A. The torque developed when the armature current is 20 A, is54 Nm81 Nm108 Nmnone of the above.⇒ Consider the following stetements For a uniform plane electromagnetic wave 1. The direction of energy flow is the same as the direction of propagation of the wave. 2. Electric and magnetic fields are in time quadrature. 3. Electric and magnetic fields are in space quadrature2 alone is correct.1 and 2 are correct1 and 3 are correct.3 alone is correct⇒ In comparison to mercury arc rectifiers metal rectifiersoperate on low temperatures.can operate on high voltages.can operate on high loads.give poor voltage regulation.⇒ The seventh space harmonics in the mmf produced by balanced fundamental frequency armature currents rotate at ____ times the synchronous speed with respect to the field.5/78/76/77/6⇒ Which of the following statements regarding repulsion induction motor is wrong?At start squirrel cage winding does not produce any torque.At start and at low speeds, major part of the torque is developed by repulsion winding.At rated load it almost runs at synchronous speed.It employes centrifugally operated mechanism for shortcircuiting the commutator⇒ Which of the following is not the advantage of a synchronous motor?High operation efficiencyOperation over a wide range of power factor-from lagging to leadingIt can always be adjusted to operate at unity power for optimum efficiency and economyIts rotor has 2 slip-rings⇒ If P1 and P2 be the iron and copper losses of a transformer at fullload and the maximum efficiency isa] 75% of the full-load, then what is the ratio of P1 and P2?9/1610/163/43/16⇒ The commutating flux produced by interpole must be proportional toarmature current.field current.both armature and field currents.none of the above.⇒ Ferrite cores are employed in high frequency transformers due to theirlow resistance.high resistance.low permeability.high hysteresis loss.⇒ The iron core in a transformer provides a____ path to the main flux.low reluctancehigh reluctancelow resistancehigh conductivity⇒ The efficiency of a 100 kVA transformer is 0.98 at full as well as half load. For this transformer at full-load the copper lossis less than core less.is equal to core lOSS.is more than core loss.none of the above.⇒ Efficiency of a dc shunt machine can be computed by knowingoutput and input.rating of machine and account of constant losses and armature resistance.either (a) or (b).⇒ The primary winding of a Schrage motor is locatedin statorin lower part ofthe rotor.in upper part of the rotor.partly in stator and partly in rotor.⇒ In a dc compound motor, 4-point starter is employedto reduce the field current.to increase the field current.not to affect the current flowing through 'Hold On' coil even when the field current changesnone of the above⇒ Atwo-winding 220 V/110 V, 1.5 kVAtransfornier is reconnected as a 220/3 30 V autotransformer, It is re-rated as:3.88 kVA4.488 kVA1.58 kVA2.258 kVA⇒ A synchrnous motor, connected to an infinite bus, is working at a leading power factor. Its excitation emf Ef and terminal voltage Vf are related as underEf > Vt and Ef lags VtEf < Vt and Ef lags VtEf > Vt and Ef leads VtEf < Vt and Ef leads Vt⇒ In a dc machine without any bnish shift, the shift of the magnetic neutral axis owing to armature reaction isin the direction of rotation for both the generator and the motoragainst the direction of rotation for both the generator and the motorin the direction of rotation for the generator and against the direction of rotation for the motor.against the direction of rotation for the generator and in the direction of rotation of motor. Free Practice With Testbook Mock Tests Options: In a salient pole machine, the direct axis synchronous reactance is greater than the quadrature axis synchronous reactance Damper bars help the synchronous motor self-start Short circuit ratio is the ratio of the field current required to produce the rated voltage on open circuit to the rated armature current. The V curve of a synchronous motor represents the variation in the armature current with field excitation, at a given output power This question was previously asked in Solution: Download Question With Solution PDF ›› Short Circuit Ratio: It is defined as the ratio of the field current (Ifoc) required to generate rated voltage on an open circuit to the field current (Ifsc) required to circulate rated armature current on a short circuit. SCR = Ifoc / Ifsc For cylindrical rotor machines, the value of SCR lies between 0.5 to 0.9. In the case of the Salient-pole machine, it lies between 1 to 1.5 For synchronous compensators, it is 0.4. In a salient pole machine, the direct axis synchronous reactance is greater than the quadrature axis synchronous reactance, due to the minimum reluctance path offered in the direct axis, and the maximum reluctance path is offered in the quadrature axis. Damper Windings: Damper windings helps the synchronous motor to start on its own (self-starting machine) by providing starting torque. By providing damper windings in the rotor of synchronous motor "Hunting of machine" can be suppressed. The performance characteristics of a synchronous motor are obtained by v-curves and inverted v-curves. V curve: For synchronous machine If the armature current Ia is plotted against excitation or field current for various load conditions, we obtain a set of curves known as V-Curves Inverted V-Curve: If the power factor is plotted against excitation for various load conditions, we obtain a set of curves known as inverted V-Curves. Download Question With Solution PDF ›› Dean B. Harrington, in Encyclopedia of Physical Science and Technology (Third Edition), 2003In synchronous machine analysis, the term "transient" may take on a special significance (in distinction from the topic to be treated next), namely, to describe a slowly varying condition, lasting perhaps a half of a second or more. Under these conditions, the changing flux produced by the changing armature current in the direct axis induces a voltage in the field winding, resulting in a field current that opposes the change in flux and hence the change in armature current. This makes it more difficult for the armature-produced magnetic flux to pass through the generator than in the steady condition. Under the transient condition, only the leakage flux paths of the armature and field windings are available, meaning fewer flux linkages per armature ampere. The result is that the generator "looks" like a reactance in the range of 0.15–0.35 per unit, much smaller than the synchronous reactance. This is called the "transient reactance" X′d.The transient reactance is important in studying transient stability, which is the ability of the power system to recover from a short circuit that has been interrupted, perhaps by circuit-breaker action.Leo Birenbaum, Enrico Levi, in Encyclopedia of Physical Science and Technology (Third Edition), 2003Figure 18 shows a synchronous machine designed to generate power in the 200-MW (megawatt) range in a thermal power plant. The driving steam turbine is on the same shaft. High-pressure, high-temperature steam (~3000 psi, 1000 °F in a coal- or oil-fired plant) is directed at the turbine blades, providing the motive power for the rotor, which induces three-phase ac voltages in the stator windings. Such a machine turns at 1800 or 3600 rpm if it generates 60 Hz and 1500 or 3000 rpm if it generates 50 Hz. In general, because of the relation between economical speed and pressure in the steam turbine, the higher generator speeds are used for the high-pressure turbine stages in fossil-fuel plants and the lower-generator speeds for the low-pressure turbine stages in fossil-fuel plants and in nuclear plants.FIGURE 18. Sketch of 3600-rpm steam turbine generator unit.The rotor is basically a rotating magnet structure with poles of alternating polarity (Fig. 19), created by appropriate windings placed in slots on the silicon steel rotor structure and firmly held there against the action of strong centrifugal forces. Direct currents are fed into the rotor windings by dc voltages often created by dc generators ("exciters") mechanically driven by the turbine also, but through a reducing gear arrangement. Such a rotor is called a round rotor, as opposed to the salient-pole rotor used in hydroelectric plant generators, which are driven by water turbines, turn much more slowly, require many more poles, and have a cross section exhibiting one saliency per pole.FIGURE 19. Types of rotors in a synchronous machine. (a) Round rotor; (b) salient-pole rotor.When a separate dc exciter is used, the dc current is supplied to the rotor through two "slip rings" mounted on and concentric with the rotor shaft, but insulated from it, through stationary brushes. Other arrangements for field excitation are also used, one being a separate alternator mounted on the rotor shaft with direct rectification of the ac voltage. This eliminates the need for slip rings.Even though large generators have efficiencies well in excess of 90%, the energy dissipated (as heat) per second may amount to several megawatts. Means of adequate cooling must therefore be provided. The best coolant is water, which is made to flow inside the hollow copper conductors. In view of the difficulty of maintaining the necessary electrical insulation in the stator and leakproof seals in the rotor, such a cooling method is justified only in sizes above 200 MW. In special applications water or oil outside the conductor is used. Hydrogen is the second best choice as a coolant but, because of its explosive nature, is not used in sizes below ~20 MW. All other machines are cooled by air, and this includes most of the motors.Synchronous motors are used mainly because of their capacity to improve the power factor of a system. At the lower end of the power range are the clock motors. Altogether, synchronous machines cover a power range that extends over 12 orders of magnitude.Sheppard Joel Salon, in The Electrical Engineering Handbook, 2005There are two standard tests that are performed on synchronous machines to determine their steady state parameters and verify the design. These are the open circuit saturation test and the steady-state short circuit test (also known as the synchronous impedance test). In the open circuit test, the machine is run at rated speed with the stator winding open circuited. The field current is varied, and the terminal voltage is plotted as a function of the field current. A typical test is shown in Figure 4.26.FIGURE 4.26. Open Circuit TestAs the field current rises the stator voltage increases proportionally. For most machines at about 80% of rated voltage, the curve becomes nonlinear, showing the effects of magnetic saturation. If the straight line characteristic is continued, the so-called air-gap line results, which is shown dotted in the figure.In the short circuit test, the rotor is turned at rated speed with a three-phase short circuit on the stator. As before, increasing the field current allows the plotting of the stator current versus the field current. A typical short circuit characteristic is also shown in Figure 4.26. The short circuit characteristic is linear. The flux density in the machine is very low since the terminal voltage is zero. The air-gap flux is sufficient to produce a voltage to overcome the leakage reactance drop.From these two curves, the synchronous reactance can be found. For the open circuit condition, the terminal voltage is equal to the internal voltage Ei.For the same field current, take the stator current from the short circuit test and find Xs as Xs = Ei/Ia. Referring to the figure, the synchronous reactance is Xs = 13,500/6,700 = 2.01 Ω.Mani Venkatasubramanian, Kevin Tomsovic, in The Electrical Engineering Handbook, 2005Three-phase synchronous generators produce the overwhelming majority of electricity in modern power systems. Synchronous machines operate by applying a dc excitation to a rotor that, when mechanically rotated, induces a voltage in the armature windings due to changing flux linkage. The per phase flux for a balanced connection can be written as:where If is the field current, θm is the angle of the rotor relative to the armature, and Kf is a constant that depends on the number of windings and the physical properties of the machine. The machine may have several poles so that the armature will "see" multiple rotations for each turn of the rotor. So, for example, a four pole machine appears electrically to be rotating twice as fast as two pole machine. For a machine rotating at ωm radions per second with p poles, the electric frequency is as follows:with ωs as the desired synchronous frequency. If the machine is rotated at a constant speed Faraday's law indicates that the induced voltage can be written as:(7.32)V=dλdt=KfIfωssin(ωst+θ0).If a load is applied to the armature windings, then current will flow and the armature flux will link with the field. This effectively puts a mechanical load on the rotor, and power input must be matched to this load to maintain the desired constant frequency. Some of the armature flux "leaks" and does not link with the field. In addition, there are winding resistive losses, but those are commonly neglected. The circuit model shown in Figure 7.8 is a good representation for the synchronous generator in the steady-state. Note that most generators are operated at some fixed terminal voltage with a constant power output. Thus, for steady-state studies, the generator is often referred to as a PV bus since the terminal node has fixed power P and voltage V.FIGURE 7.8. Simple Synchronous Generator ModelS. Puppin, ... R. Sartori, in Fusion Technology 1996, 1997One fundamental hypothesis of the decoupling control algorithm is that all power supplies should behave as ideal voltage amplifiers. In JET, with the exception of the P1 coil circuit (the central solenoid), this assumption is well fulfilled.The central solenoid is powered by the PFGC (Poloidal Field Generator-Converter, synchronous machine with diode rectifier). The input-output characteristic of this assembly is highly non-linear. In the Mark I campaign this non linearity was limiting the plasma current control performance (Figure 6 (a)).Figure 6. Comparison of the performance of the plasma current control.To compensate for this limitation, a new voltage loop (equation (9)) has been added around the PFGC, using as feedback quantity the measurement of the central solenoid voltage.(9)VPFgen_ref = 255NPFGC Kp(1+ sτd + 1s τi)· ΔVΔV (Vpl_ref− Vpl)NPFGC is the PFGC speed. With the new loop, the control of the plasma current can be made much faster than what is required in normal operation (Figure 6(b)).Sergio Rivera, ... Kamal Youcef-Toumi, in Industrial Agents, 2015The differential algebraic equations that describe the dynamics of the multiple microgrids are presented based upon the models given in Gomez Exposito et al. (2009). The differential equations describe the dynamics of the dispatchable generators and loads and are simply modeled as either a damped synchronous generator or motor, respectively (Gomez Exposito et al., 2009). Each synchronous machine i is described by Equation (15.1):(15.1)δi=ωi−ω0ω˙i=ω02HiPmi−Peiδ−Diωiwhere δi is the machine phase angle, ωi is the angular frequency, Hi is the mechanical inertia, Di is the damping, Pmi is the dispatchable power applied to the prime mover, and Pei is the electrical power at generator i, which is a nonlinear function of the machine phase angles. The dynamics of each synchronous machine are coupled by the power flows through the grid topologies, as shown in Equation (15.2):where E is the system bus voltage and Y is the system admittance matrix; detailed formulation is in Gomez Exposito et al. (2009). The stochastic generators (i.e., solar PV and wind) and noncontrollable loads are modeled as static power injections that affect the system admittance matrix (Gomez Exposito et al., 2009). These equations can be thought to apply to each microgrid when they are mutually disconnected or to the aggregation of microgrids when the admittance matrix has been manipulated to reflect their interconnectedness.The microgrid agents dispatch their dispatchable elements autonomously with the dispatchMicroGrid method. In practice, this is implemented by calling an economic dispatch program written in the General Algebraic Modeling System (GAMS), RunGAMS class in Figure 15.3. In this control approach, each microgrid agent implements its own model predictive control (MPC), as an economic dispatch method, which is able to dispatch the mechanical power setpoints Pmi for the synchronous machines within its control area. The MPC uses a time horizon of 4 time blocks of 15-second duration and dispatches Pmi for the first time block in each generator. The MPC formulation is as follows:(15.3)min∑t=kK∑i=1NGCiF+CiGPmi,tG(15.4)s.t.∑i=1NGPmi,tG=PNLt(15.5)−RiG,min≤Pmi,tG−Pmi,t−1G≤RiG,max(15.6)−PmiG,min≤Pmi,tG≤PmiG,maxwhere the following notations are used:CiF,CiG:fixed and generation (fuel) costs of generator iPmi,sG: power output of generator i at time tPNLt:netload forecast at time tRiG,max,RiG,min:max/minramping rate of generator iPiG,max,PiG,min:max/minpower limits of generator iNG:number of generatorsEnrico Levi, in Encyclopedia of Physical Science and Technology (Third Edition), 2003Rotating machines are subjected to spot checks in the smaller sizes and individual checks in the larger sizes, by the manufacturers. Compliance with the standards is determined by recommended test procedures, such as ANSI/IEEE St. 112-1978 for Polyphase Induction Motors and Generators, IEEE Publ. No. 115 and ANSI C50.10-1965 for Synchronous Machines, and IEEE St. 11-1980 for Rotating Electrical Machinery for Rail and Road Vehicles. Routine tests consist of measurements of winding resistances, high-potential tests at twice the rated voltage plus 1000 V; no-load readings of current, power, and nominal speed at rated voltage and frequency in induction motors; and measurement of open-circuit voltage ratio in wound-rotor induction motors. Specific tests include measurements of; (1) the acoustic noise, which, when certain frequencies are omitted to match the frequency response of the human ear (A network), should not exceed ~120 dB referred to 10−12 W, (2) the critical torques in motors, and (3) the harmonic content of the voltage wave in ac generators. The latter is specified in terms of two factors, which are defined in ANSI C42.10 with limiting values given in ANSI C50.12, C50.13, and C50.14 as follows:1.The deviation factor is the maximum difference between the ordinates of the open-circuit terminal voltage wave and of the equivalent sine wave divided by the amplitude of the equivalent sine wave. Its limiting values are of the order of 0.1.2.The telephone influence factor (TIF) is the sum of all the harmonics in the voltage wave weighted to reflect their relative objectional effect on telephone communications. The weighing factor ranges from 0.5 at 60 Hz to a peak of 10,600 at 2580 Hz. The limiting values of TIF are of the order of 100.There are a number of test methods for determining the efficiency of rotating machines. Because efficiencies are relatively high—in large sizes and in special-design small sizes they exceed 90%—very accurate measurements of the electrical quantities, torque, and speed are needed. A common method is to couple a motor and a generator in a set called the dynamometer and to measure the power input and output. Alternatively, one can assess the individual components of the losses. These are discussed in detail in Section III. The recent concern with energy conservation has prompted NEMA to improve the evaluation of efficiency in polyphase induction motors between 1 and 125 hp. A new standard MG1-12.53 has been adopted. Part (a) deals with testing procedures and aims at determining the efficiency with precision better than 1%. Part (b) deals with the variances that result from materials, components, and manufacturing limitations. It establishes a table defining a nominal full-load efficiency, which is the average value in a large population of motors of the same design, and a minimum value, which is based on an increment of 20% in the losses.The losses not only are an important factor in the economic evaluation process, but also lead to a thermal limitation in the rating of the motor. In general, the lifetime of the insulation decays exponentially with the temperature rise and, in the range of practical interest, it is reduced by about one-half with every increase in temperature of ~10 K. As a result, standards establish that the temperature rise over a 40 °C ambient temperature, when measured by the increase in resistance of the winding or by thermocouples, should not exceed prescribed limits. Typical values are as follows: 60 K for class A insulation, which comprises organic materials; 80 K for class B insulation, which comprises inorganic materials and synthetic films; 105 K for class F, which comprises materials similar to those of class B but with higher-temperature binders; and 125 K for class H, which includes silicon elastometers, as well as inorganic materials (MGl-12.41, 12.42, 21.40, 22.40, 23.40, 24.40, 1.65). The stated temperature rises ensure a life expectancy of 20,000–40,000 hr.The allowable temperature rise defines the rating of the machine. The most common is the continuous rating defining the output that can be carried indefinitely. For intermittent, periodic, or varying duty a machine may be given a short-time rating defining the load that can be carried for a specific time. Standard periods for short-time ratings depend on the thermal time constant and therefore on the size of the machine. They are as follows: 5 min up to 39 hp, 15 min up to 50 hp, 30 min up to 60 hp, and 60 min up to 70 hp. The short-time load test commences only when the windings and other parts of the machine are within 5 K of the ambient temperature at the time of the starting of the test (MG1-10.35). The permissible temperature rises quoted above apply to open, general-purpose motors for which service conditions are unknown. Higher temperature rises are allowed for special-purpose motors that are designed with either operating characteristics or mechanical construction or both for a particular application. As a way to compensate for the lower rise, general-purpose motors are allowed a service factor of 1.15 when operated at rated voltage. Service factor is a multiplier that, when applied to the rated output, indicates a permissible loading that may be carried under the conditions specified for the service factor (MG1-14.35).In general, electrical machines require much less maintenance than other types of machinery. The insulation resistance to ground is a good index of the state of the windings and should be checked periodically. Its value in megohms should exceed 1 MΩ plus the rated machine potential in kilovolts. The only parts requiring maintenance are surfaces that are in relative motion, such as bearing surfaces. Sliding contacts that carry electrical currents, such as the contacts between brushes and slip rings and commutators, operate at higher temperatures and may be subjected to pitting due to sparks. As a result they may require more frequent maintenance. This consists of cleaning and blowing out the conducting dust resulting from brush wear, adjusting and replacing brushes, and polishing, grinding, and turning slip rings and commutators. Whether the mica between commutator segments should be left flush with the copper surface or be recessed (i.e., undercut) is debatable. In any case, properly designed rotating machines can operate for thousands of hours without requiring maintenance.Mladen Kezunovic, in The Electrical Engineering Handbook, 2005Synchronous generators are commonly used in high-voltage power systems to generate electric power. They are also protected using the current differential relaying principle. In addition, the generators require a number of other special operating conditions to be met. This leads to the use of a score of other relaying principles. This section reviews some basic requirements for generator protection and discusses the basic relaying principles used. A much more comprehensive coverage of the subject may be found in an IEEE Tutorial (1995).Generators need to be protected from the internal faults as well as the abnormal operating conditions. Since generators consist of two parts, namely the stator and the rotor, protection of both is required. The stator is protected from both phase and ground faults, while the rotor is protected against ground faults and loss of field excitation. Due to the particular conditions required for the synchronous machine to operate, a number of operating conditions that represent either a power system disturbance or operational hazard need to be avoided. The conditions associated with network disturbances are overvoltage or undervoltage, unbalanced currents, network frequency deviation, and subsynchronous oscillations. The conditions of hazardous operation are loss of prime mover (better known as generator motoring), inadvertent energization causing a nonsynchronized connection, overload, out-of-step or loss of synchronism, and operation at unallowed frequencies.The current differential protection principle is most commonly used to protect against phase faults on the stator, which are the most common faults. Other conditions require other principles to be used. The loss of field and the ground protection of the rotor are quite complex and depend on the type of the grounding and current sensing arrangement used. This subject is well beyond the basic considerations and is treated in a variety of specialized literature (IEEE, 1995). Protection from the abnormal generator operating condition requires the use of relaying principles based on detection of the changes in voltage, current, power, or frequency. A reverse power relay is used to protect against loss of a prime mover known as generator motoring, which is a dangerous condition since it can cause damage of the turbine and turbine blades. In addition, synchronous generators should not be subjected to an overvoltage. With normal operation near the knee of the iron saturation curve, small overvoltages result in excessive flux densities and abnormal flux patterns, which can cause extensive structural damage in the machine. A relaying principle based on the ratio between voltage and frequency, called a volt-per-hertz principle, is used to detect this condition. An inadvertent connection of the generator to the power system not meeting the synchronization requirements can also cause damage. The overcurrent relaying principle in combination with the reverse power principle are used to detect such conditions. The overload conditions as well as over- and under-frequency operations can cause damage from overheating, and thermal relays in combination with frequency relays are used. Undervoltage and overvoltage protections are used for detecting loss of synchronism and overvoltage conditions.Stylianos Basagiannis, ... Menouer Boubekeur, in Smart Grid Security, 2015Distributed generation with a high penetration of renewable energy sources and low-carbon technologies is accepted as an alternative for traditional centralized power plants (Kroposki et al., 2008). The microgrid concept has emerged as the local-level integration and coordination of distribution energy resources, and enables the reduction of running cost and green house gas emissions, as well as guarantee availability of power supply, among other benefits (WBCSD, 2007). The microgrid concept can be extended to commercial and residential buildings, where there are growing opportunities for reduction of energy consumption and new market opportunities for stakeholders. Those sectors consume around 40% of total energy use in industrial societies (Scenarios for a clean energy future, 2000), and account for nearly one-third of greenhouse gas emissions. On the other hand, the security of microgrids increasingly comes as second priority. Especially when the integration of heterogeneous systems inside a building is rising, weak security implementations of the individual components cause critical vulnerabilities. To this end, different control strategies residing either in local embedded controllers of the components, or high level control up to the SCADA system can cause system instability, which can easily result in major grid faults.We are going to describe common control strategies that are often implemented in smart grids. We select to focus on the test-bed microgrid (Valdivia et al., 2014) which is composed of different components all controlled through a SCADA system. Although it is a small-case system only, hierarchical control strategies assure the optimal operation of all of the sub-systems, and it applis a multidisciplinary approach consisting of information and communication technologies (ICT), power systems, power electronics, controls and optimization, and diagnostics. The electrical microgrid incorporates a 10 kW wind Turbine (Bergey Excelsys), a 35 kWh (85 kW peak) Li-Ion battery (Saft), a 50 kW electrical/82 kW thermal combined heat and power unit (CHP) by Sokratherm, a feeder management relay at the point of coupling between the microgrid and the rest of the building, and a set of local loads. Both the battery and the wind turbine are interfaced with the microgrid through power electronics converters (Triphase and Aurora, respectively), while the CHP is interconnected through a synchronous machine. This structure incorporates all of the major components in microgrids, such as renewable generation, Internal Combustion (IC) based generation, storage and different kind of interfaces. Thus, different control strategies on different hierarchical layers, stability issues (such as those resulting from synchronous machines interfacing controlled power electronics converters) and seamless transition from island to grid-connected mode, among others, can be evaluated. For further information the reader can refer to (Valdivia et al., 2014).Originally an integrated test-bed like the one described in (Valdivia et al., 2014) is controlled by following the hierarchical three-layer architecture illustrated in Figure 10.2. Similar approaches have been reported in (Lopes et al., 2006; Vasquez et al., 2010).Figure 10.2. Hierarchical control of the building-level electrical microgrid and thermal systemTertiary control is performed by an integrated energy management system based on model predictive control. Recent efforts have focused on the application of predictive control to heating, ventilation, and air conditioning (HVAC) systems in energy efficient buildings (Ma et al., 2012; Samad & Kiliccote, 2012) thereby not including electrical local generation and storage. Here, the supervisory control considers the electrical microgrid components as well as heating system (including boiler, CHP, storage components), and computes the optimal set-points of them such that the running energy cost is minimized (Xiaohong et al., 2010). Electrical and thermal load forecasts as well as gas/electricity pricing and weather forecasts are exploited to achieve this goal. The problem is cast as mixed integer linear programming provided that all the equipment models are conveniently linearized.The secondary control is used to perform coordination tasks and is implemented by two dedicated control units:1.Programmable Logic Controller (PLC) and a Supervisory Control and Data Acquisition (SCADA) system: This system performs central control of the electrical microgrid. It performs tasks such as detection, seamless islanding transition and reconnection via a Feeder Management Relay (FMR), as well as load balancing under islanding conditions. This also receives set points from tertiary control for the different subsystems and sends them as inputs to the primary controllers via standard communications (Modbus) and analog/digital signals. This layer can also include provision of ancillary services to the utility grid. An overview of the SCADA Human Machine Interface is shown in Figure 10.3. under operation in islanded conditions.Figure 10.3. Overview of BMS HMI and system operation2.Building Management System (BMS): Figure 10.3 shows also the BMS for the building heating system that implements the local controller algorithms for thermal system components. The two boilers that provide hot water to the main heater are controlled using an On/Off algorithm to regulate the flow temperature to its set-point. A PI algorithm is used to regulate the flow temperature for each mixing valve. The radiators are modulated by on-off thermostats to maintain zone temperatures close to the user-selected set-points. Figure 10.3 shows the BMS HMI for boiler management and experimental temperature profiles over one week. This is a simple operation example where the boiler and mixing valve are scheduled to be active at 7am and off at 9pm and during the weekend (3/23/2013 and 3/24/2013).The primary control layer is embedded in the generators and is responsible for assuring the stability of the electrical system and the correct dynamics and power quality. Thermal system local controllers are PI for mixing valve control, and On/Off for radiators and boiler control.Figure 10.4 illustrates a detail of the power electronics converter for the battery. A multi-stage DC-DC converter boosts the battery voltage (360-480 V approx.) to 650 V approx. This converter also controls the DC link voltage using a multi-loop strategy. The three-phase DC-AC converter controls the AC-side current in d-q frame using a PI control plus resonators for harmonic compensation. This control structure for the DC-AC stage (herein shown for grid-follower operation) can be easily completed with an external voltage control for grid-forming operation. The set points for the grid-current are managed by the secondary control layer (the SCADA system), which receives inputs such as state of charge and maximum power available from the battery management system.Figure 10.4. Battery inverter local controller (grid-follower strategy)A critical issue related to system stability comes from the fact that the grid impedance in island conditions is significantly larger than that under grid-connected conditions. This can influence significantly the current control loop dynamics, so that a controller stable under grid-connected mode can be unstable in island mode. Figure 10.5 illustrates the plan of the current loop for different grid inductances (having feed-forward of grid voltage and considering digital delays). A substantial phase and magnitude drop is observed above 400 Hz with large inductance.Figure 10.5. Influence of grid-impedance on inner plant dynamics (current-loop) in power convertersFigure 10.6 shows results corresponding to an islanding transition. At the time of islanding, the microgrid was exporting 18 kW at the point of common coupling. As can be seen, the microgrid remains stable with similar total harmonic distortion (THD) less than 2%. Load balancing algorithms are applied to compensate the instantaneous power unbalance at the time of islanding, leading to only 3% overvoltage compared to the final steady-state value.Figure 10.6. Experimental Transition from grid-connected (parallel) mode to islanded modeAfter describing low and high level control strategies, it should be also noted that security is tightly connected to a common secure flow of information that is centrally inspected but locally generated from the components of the grid. Even in case of a small-scale power plant that requires a hierarchical control strategy to assure the optimal operation of all the sub-systems. This involves a multidisciplinary approach which includes information and communication technologies (ICT), that malicious users can exploit. Cyber security attempts can be sourced due to small alert deactivation that an intruder can perform. Notifications and fake true-positives (on the SCADA level) can be easily set up if an intruder will have access to the communication medium and deflect alert messages from its intended recipient. For example, if a smart meter is hacked, not issuing messages when the battery component of the grid is charging, the SCADA centralized decision algorithms can go ahead with legitimate but not authorized operations, bringing the battery component to danger, and thus the grid at risk.Khalid Mehmood Cheema, in International Journal of Electrical Power & Energy Systems, 2020Few other topologies and techniques are introduced in different research work such as Virtual synchronous machine (VISMA) and Institute of electrical power engineering (IEPE) technique [41,42]. The fundamental idea to mimic inertia response is uniform for all topologies. The VISMA technique used d-q based architecture to mimic the synchronous generator in the research work of [43]. When this architectural design applied through a digital control unit of power inverter, then it copies the dynamics of synchronous generator. However, in literature, it is discussed that VISMA technique is unstable due to numerical data involvement. In [44], instead of d-q model, a new approach is developed to increase the strength by using a three-phase model. This new technique is highly efficient for asymmetrical loads and sharp changes in the utility grid.IEPE topology is another topology which is somewhat similar to VISMA, but the significant difference is that IEPE used output current of a DG and then produce reference voltage for virtual machines. In grid connected mode of IEPE, it is problematic to cope with transient currents in the synchronization period. However, for islanded mode, IEPE technique is best fitted.