# Capability curve pdf

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Please share and spread the word: The generator operating point limits are stated and visualized in the form of the generator capability curve. The generator load capability curve and generator operating capability include active power (MW), reactive power (MVAr), and apparent power (MVA). The capability curve is drawn on the PQ axis. Where P is in MW and Q is in MVAr. Information derived from the Generator Capability Curve: Maximum generation limit.Determine the operating limit of the generator’s steady-state stability.Limitation of the constraints on the various elements of the generator.To improve the active power pricing mechanism by considering the reactive power component.Determine the settings of the protection system by knowing the safe operating limits of the generator.Minimum limit in under-excitation conditions. Generator Characteristics: Synchronous generators are rated in terms of the maximum MVA at a specified voltage and power factor (usually 0.85 or 0.9 lagging). The active power output is limited by the prime mover. The continuous reactive power output capability is limited by three considerations: Armature current limit, Field current limit, and End region heating limit. A Synchronous machine cannot be operated at all points inside the region bounded by the circle shown in the below figure without exceeding the machine rating. Generator Capability Curve Generator Limitations: There are 6 principal limitations on the generator operation. 1. Stator winding heating limit. 2. MW limit. 3. Rotor heating limit. 4. Steady-state Stability limit. 5. Stator core end heating limit. 6. VOLTAGE Instability at Leading Power factors. 1. Stator Winding Heating Limit: The generator stator conductors are operating at their thermal limit. This limit is due to I square R heating in the stator conductors. If the generator power factor is altered to a value nearer to UPF, then due to the lower stator current, the generator stator conductors would be operating well within their thermal limit. One of the limitations of generator rating is the maximum current that can be carried by the armature without exceeding the heating limitations. Therefore, in the P-Q plane the armature current limit, as shown in Figure, appears as a circle with a center at the origin and a radius equal to the MVA rating. Synchronous Machine Capability Curves The circle with center at the origin O and radius S= Vt*Ia defines the region of operation for which armature heating will not exceed a specified limit. 2. MW Limit: MW output is limited by turbine output and stator conductor heating. The real power output of the generator is usually limited to a value within the apparent power rating by the capability of its prime mover. Maximum prime mover capability is generally smaller than the maximum active power that is limited by the generator stator current. 3. Rotor Heating Limit: Rotor currents caused heat resulting from I square R losses, the field current imposes a second limit on the operation of the generator. Due to this limitation rotor conductors are unable to carry larger currents to the rotor. This limit affects the capability of the machine in over-excited conditions. 4. Steady-state Stability Limit: The steady-state stability limit is the maximum power that can be transferred without the system becoming unstable when the load is increased gradually, under steady-state conditions. In the case of a generator operating with a leading power factor, the excitation and hence flux produced by the rotor is weak. Consequently, the magnetic coupling between the rotor and stator rotating magnetic fields is also weak. If the generator is loaded under this condition, a large load angle (rotor angle) is produced. When this load angle reaches 90°, the generator is producing the maximum amount of power for the excitation being used and is said to be operating at its steady-state stability limit. Generator Power Angle Curve Any further increase in load will cause the magnetic fluxes to stretch further and the load angle to increase further. A point is reached when the rotor is at the 180 Deg position, where there is no magnetic coupling between the rotor and stator. When this occurs, the rotor will speed up and the generator, instead of giving a steady output, will only give surges of power as the rotor N pole passes the stator S pole. This effect is known as “pole slipping” and the generator is now unstable. The large surges of power, from a mechanical point of view, puts great strain on the generator to turbine coupling, the bearings, and foundations. From an electrical point of view, the surges of power will cause current surges and hence magnetic stresses to all load-carrying components. These surges of power will also cause the voltages to fluctuate rapidly and cause lights to flash. To make sure that the generator will remain stable, it must not be operated with more leading vars than is shown by the stability limit line. The horizontal line XYZ specifies the steady-state stability limit. 5. Stator Core End Heating Limit: When a generator is operating at unity or lagging power factor, a strong flux is produced by the rotor. Under this condition, little flux is able to leak out from the ends of the stator -core and there is no excessive heating at the core ends. Stator Core End Region Heating When the generator is operating at a leading power factor, the flux produced by the rotor is weaker and more flux is able to leak out from the ends of the stator core. When this flux leaks out from the ends of the stator core, it passes through the face of each lamination and causes large eddy currents to flow in these laminations. These eddy currents can cause excessive heating. 6. Voltage Instability at Leading Power Factors: Terminal voltage output is limited by the heating of the stator iron core, as distinct from the core end heating. CONCLUSION: Therefore, for a generator operating at its rated speed (frequency) the: MW output is limited by turbine output and stator conductor heating.Mvar output (lag) is limited by the rotor heating.Mvar output (lead) is limited by stator core end heating and also by stability considerations.Terminal voltage output is limited by the heating of the stator iron core. The Capability Curve of a Synchronous Generator defines a boundary within which the machine can operate safely. It is also known as Operating Charts or Capability Charts. The permissible region of operation is restricted to the following points given below: The MVA loading should not exceed the generator rating. This limit is determined by the armature of the stator heating by the armature current. The MW loading should not exceed the rating of the prime mover. The field current should not be allowed to exceed a specified value determined by the heating of the field. For steady-state or stable operation, the load angle $\delta$ must be less than 90 degrees. The theoretical stability limit of the stable condition occurs when $\delta = 90^0$. The capability curve is based upon the phasor diagram of the synchronous machine. The phasor diagram of a cylindrical rotor alternator at lagging power factor is shown below: For simplicity, the armature resistance and saturation are assumed to be negligible. The machine is assumed to be connected to constant voltage busbars so that the voltage Vp is constant. The length O’O (= Vp) is fixed. The axes Ox and Oy are drawn with their origin O at the tip of Vp. From the phasor diagram, The real power output of the generator is given as: The reactive power output of the generator is given as: A typical capability curve for a cylindrical rotor generator is shown below: The curve is plotted on the S-plane, where P is the vertical axis and Q is the horizontal axis. For constant power Ia and volt-amperes S = VA, the locus is a circle with a center at O and radius OB (= 3 Vp Ia). Constant P operation lies on a line parallel to Q axis. The constant excitation locus is a circle with center O’ and radius O’B ( = 3 Vp Ef/Xs). Constant power factor lines are straight radial lines from O. For excitation Ef equal to zero, the armature current is given as: = short circuit current at rated voltage = OO’ The theoretical stability limit is a straight line O’M at right angles to O’O at O’. Here $\delta = 90^0$. Between a and b, the operation of the alternator is limited by the maximum field current, and a circle of radius (3 V Ef/ Xs) with center O’. Between b and c, the operation is limited by the MVA limit. Here Ia is the maximum permissible armature current. Between c and d, the operation is limited by the power of the prime mover. Between d and e, the operation is limited by the practical stability limit. The theoretical limit of stability occurs where $\delta = 90^0$. But there must be a safety margin between the theoretical limit and that used in practice. The practical limit is usually taken 10% less than the theoretical stability limit. The complete operating zone of the alternator is abcdkOa. The operation of the alternator within this area is safe from the standpoints of heating and stability. Once an operating point is located within this area, the desired power P, S, Q i.e., Current, power factor, and excitation are found. Consider the figure given below. Here an operating point F is considered, and the following information is given: If point F is inside the capability curve, the machine will not be overheated and will not be likely to fall out of synchronism. A line from F to the origin O’ of the If is at an angle $\delta$ from the axis. A line FG through F parallel to O’Oa give power equal to OG. A line from F to the origin O of the Q axis gives the power factor angle $\phi$ from the vertical axis. i.e., $\angle FOG = \phi$ The armature current Ia is given by OF. The VA output is given by (OF x operating voltage) The VAr output is given by GF x output voltage O’F gives the excitation Ef. This is all about capability curve.

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