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MMF method is used for determining the voltage regulation of an alternator or synchronous generator is also called Ampere turns method or Rothert's MMF method. This MMF method is based on the results of open circuit test and short circuit test on an alternator. For any synchronous generator or alternator, MMF is required, which is a product of field current and turns of the field winding for two separate purposes. 1. It must have an MMF necessary to induce the rated terminal voltage on the open circuit. 2. It must have an MMF equal and opposite to that of armature reaction MMF. Key Point: In most of the cases, as the number of turns on the field winding is not known, the MMF is calculated and expressed in terms of the field current itself. The field mmf which is required for inducing the rated terminal voltage on the open circuit can be obtained from open circuit test results and open circuit characteristics. This is denoted as FO. Synchronous impedance consists of two components. They are armature resistance and synchronous reactance. Now synchronous reactance also has two components, armature leakage reactance and armature reaction reactance. In the short-circuit test, field MMF is necessary to overcome drop across armature resistance and leakage reactance and also to overcome the effect of armature reaction. This textbook "Electrical Machinery by P.S. Bhimbhra" is the best in industry. Grab it now for very less price. But drop across armature resistance and leakage reactance is very small and can be neglected. Thus in short circuit test, field MMF circulates the full load current balancing the armature reaction effect. The value of ampere-turns required to circulate full load current can be obtained from short circuit characteristics. This is denoted as FAR. Under short circuit condition as resistance and leakage reactance of armature has no significant role, the armature reactance is dominating and hence the power factor of the purely reactive circuit is zero lagging. Hence FAR gives demagnetising ampere-turns. Thus the field MMF is entirely used to overcome the armature reaction which is wholly demagnetising in nature. The two components of total field mmf which are FO and FAR are indicated in OCC(open circuit characteristics) and SCC (short circuit characteristics) as shown in the below figure. If the alternator is supplying full load, then total field MMF is the vector sum of its two components Fo and FAR. This depends on the power factor of the load which alternator is supplying. The resultant field MMF is denoted as FR. Let us consider the various power factors and the resultant FR. Zero lagging p.f : As the power factor is zero lagging, the armature reaction is completely demagnetising. Hence the resultant FR is the algebraic sum of the two components FO and FAR. Field MMF method is not only required to produce rated terminal voltage but also required to overcome completely demagnetising armature reaction effect. It is shown if the below figure. OA = FO AB = FAR DEMAGNETISING OB = FR = FO + FAR Total field MMF is greater than Fo Zero leading p.f : When the power factor is zero leading the armature reaction is totally magnetising and helps main flux to induced rated terminal voltage. Hence net field required is less than that required to induce rated voltage normally, as part of its function is done by magnetising armature reaction component. The net field mmf in this MMF method is the algebraic difference between the two components FO and FAR. OA = FO AB = FAR MAGNETISING OB = FO – FAR = FR Total MMF is less than FO. Unity p.f : Under unity power factor condition, the armature reaction is cross magnetising and its effect is to distort the main flux. Thus FO and FAR are at right angles to each other and hence resultant MMF is the vector sum of FO and FAR in this MMF method.This is shown in the below figure. OA = FO AB = FAR CROSS MAGNETISING OB = FR = FO + FAR Here below is the following considerations for MMF or Ampere turn method for determining voltage regulation of Alternator. General Case: Now consider that the load power factor is cos Φ. In such case, the resultant MMF is to be determined by vector addition of FO and FAR. cos Φ, lagging p.f : When the load p.f. is cos Φ lagging, the phase current Iaph lags Vph by angle Φ.The component FO is at right angles to Vph while FAR is in phase with the current Iaph. This is because the armature current Iaph decides the armature reaction. The armature reaction FAR due to current Iaph is to be overcome by the field MMF. Hence while finding resultant field MMF, – FAR should be added to FO vectorially. This is because the resultant field MMF tries to counterbalance armature reaction to produce rated terminal voltage. The phasor diagram of Ampere turn method or MMF method is shown below. From the phasor diagram the various magnitudes are, OA = Fo , AB = FAR, OB = FR Consider triangle OCB which is right angle triangle. The FAR is split into two parts as, AC = FAR sin Φ and BC = FAR cos Φ FR = (FO + FAR sin Φ)² + (FAR cos Φ)² can be obtained from the above relation. Cos Φ, leading p.f : When the load p.f. is cos Φ leading, the phase current Iaph leads Vph by Φ. The component Fo is at right angles to Vph, and FAR is in phase with Iaph. The resultant FR can be obtained by adding FA to Fo. The phasor diagram is shown in the below figure. From the phasor diagram , various magnitudes are, AC = FAR sin Φ and BC = FAR cos Φ OA = FO , AB = FAR and OB = FR Consider triangle OCB which is a right angle triangle. (OB)² = (OC)² + (BC)² (FR)² = (FO – FAR sin Φ)² + (FAR cos Φ)² This textbook "Electrical Machinery by P.S. Bhimbhra" is the best in industry. Grab it now for very less price. From the relation (2), FR can be obtained, Using relations (1) and (2) resultant field MMF FR for any p.f load condition can be obtained from the above MMF characteristics diagram. Once FR is known, obtain a corresponding voltage which induced EMF Eph, required to get rated terminal voltage Vph. This is possible from open circuit characteristics drawn below. Once Eph is known then the regulation can be obtained as, Note : To obtain Eph corresponding to FR from O.C.C. must be drawn to the scale, from the open circuit test readings. Key Point: This ampere turn method gives the voltage regulation of an alternator which is lower than that actually observed. Hence this MMF method is called optimistic method. Important note: When the synchronous impedance method is used to find mmf required to produce rated Vph at the output terminals. But if the effective armature resistance Raph, is given then Fo is to be calculated from O.C.C. such that Fo represents the excitation (field current) required to produce a voltage of Vph + Iaph Ra cos Φ where Vph = rated voltage per phase Iaph = full load current per phase Ra = armature resistance per phase cos Φ = power factor of the load It can also be noted that FR can be obtained using the cosine rule to the triangle formed by Fo, FAR and Fo as shown in the below. Using cosine rule to triangle OAB, (FR)² = (FO)² + (FAR)² – 2 FO FAR Cos (FO,FAR) (FO,FAR) = 90 + Φ if Φ is lagging = 90 – Φ if Φ is leading The angle between EO and Vph is denoted as δ and is called power angle. Neglecting Ra we can write, Ia Xs cos Φ = EO sin δ Pd = Vph Ia Cos Φ = internal power of the machine Now today we have learnt MMF or Ampere turn method for determining voltage regulation of alternator. You can download this article as pdf, ppt. Comment below for any Queries. Keeping your world up and running. Our customers count on us for rugged, reliable and accurate test instruments.We offer test, measurement and monitoring products and software that are used in electronic design, manufacturing, and network troubleshooting, as well as in electrical, industrial, medical, process and calibration applications.Click below to learn more about our companies. Keeping your world up and running.®Leader in test and measurement softwareFluke Corporation is the world leader in professional electronic test tools and software for measuring and condition monitoring. Fluke tools are known for portability, safety, ease-of-use, accuracy and rigid standards of quality. Precision, performance, confidence.™A leader in precision calibration instruments, equipment, service and software for electrical, RF, temperature, pressure and flow measurements.Fluke Calibration products are all now on fluke.com! The Fluke family includes many brands around the world including PLS, Pomona and Amprobe.Please use the drop down menu below to select the company you are looking for. In the last two articles, we have seen the determination of voltage regulation using the synchronous impedance method and MMF or ampere-turn method. The drawback of the synchronous impedance method is that the regulation obtained is always higher than the actual value. While with the ampere-turn method the regulation obtained is lower than the actual value. This can be overcome by using the method called 'Potier's Triangle Method or Zero Power factor Method (ZPF)'. This method gives more accurate results in finding voltage regulation. In Potier's method, the drops due to armature leakage reactance and armature reaction effect are treated separately. While in synchronous impedance and MMF methods all the quantities are treated as emf and mmf quantities respectively (which are away from reality). In order to obtain voltage regulation using potier's method. The armature leakage reactance XL (emf quantity) and armature reaction effect (mmf quantity) are determined separately by performing two tests on the alternator.Open circuit testZero power factor test Open Circuit Test : The below shows the circuit diagram to perform the open-circuit test on the alternator with open-circuited armature terminals. The alternator is running at synchronous speed driven by the prime mover with no-load connected across the armature. The voltmeters connected across the armature open-circuited lines measure open-circuit voltage. At first, adjust the prime mover speed to the synchronous speed of the alternator. The rheostat in the field circuit (rotor) is set to its maximum value.Now increase the field current by varying the field rheostat so that flux produced by field winding increases. The increased flux increases induced emf in the armature thereby increasing the terminal voltage of the alternator.The various values of open-circuit line voltage Voc at different field current If values are noted.The below curve shows the open-circuit test characteristics drawn between field current and open-circuit voltage. Zero Power Factor Test : To perform a zero power factor test a purely inductive load is connected to the alternator i.e., across the armature terminals as shown below. At first, the alternator is made to run at its synchronous speed. Now by varying the field excitation and inductance of the inductive load the armature current is made to supply its full-load rated armature current. Since the load connected is purely inductive the alternator will operate at zero power factor lagging (cos 90°). Hence this method is also called as 'Zero Power Factor Method (ZPF)'. The below figure shows the saturation curve of terminal voltage against field excitation (field current) required to deliver full-load short-circuit armature current. Point A shows the field current corresponding to zero terminal voltage. The line OB tangent to O.C.C. is drawn called an air-gap line. The point P is obtained at rated terminal voltage while the alternator delivering full current at ZPF lagging. From P, PQ is drawn equal to OA and a line QR parallel to air-gap line which intersects O.C.C. at point R. Now draw a line from point A parallel to PR intersecting O.C.C. at point B. Thus the triangles OAB and PQR are similar triangle. Draw the perpendiculars in triangles OAB and PQR from point B and R such that they meet at point C and Q on the lines OA and PQ respectively. The triangle PQR is called potier triangle which remains constant for a given armature current. Hence it can be transferred to other points like P'Q'R' to obtain △ OAB. In the △ PQR the line RS represents the armature leakage reactance drop IXL. The length PS gives the field current Iar necessary to balance the armature reaction at full-load. Since the load is inductive the effect of armature reaction is wholly demagnetising. Similarly, the length SQ gives the field current Ir necessary to balance armature leakage reactance drop IXL. Regulation Calculation : From the graph, the armature leakage reactance XL, known as potier reactance is obtained as, To determine the regulation using potier reactance, draw the potier phasor diagram as shown. Taking V as a reference, I is drawn at lagging p.f. with angle Φ because the load is inductive. The armature resistance and armature leakage reactance drops IRa and IXL is drawn parallel and perpendicular to current I from the tip of V respectively. Phasor sum of rated voltage V, armature resistance drop IRa, and armature leakage reactance drop IXL gives induced emf E i.e., OC. The field current corresponding to E is obtained from O.C.C i.e., FF1 at 90° ahead as shown below. The induced emf obtained is without the armature reaction effect. From potier triangle, PQR the field current required to balance the armature reaction effect is obtained i.e., PS, which is say FAR. The vector sum of excitations FF1 and FAR gives the total excitation FR required to overcome both the armature leakage reactance and the armature reaction effect. Once the total excitation (field current) is known corresponding induced emf Eo is obtained from the O.C.C. Therefore, the regulation of the alternator is determined as, Assumptions in Potier Triangle Method : Some of the assumptions made while determining regulation using potier method are,The armature resistance Ra is not considered in potier method. Even though it is very small and can be neglected.The armature reaction MMF is constant.Practically it is difficult to achieve a perfect zero power factor lagging Pure inductive load. Sign Up Now 4Daily Live Classes3000+ TestsStudy Material & PDFQuizzes With Detailed Analytics+ More BenefitsGet Free Access Now Power factor is not an unknown topic for us. But still, some questions roam in our heads. We have heard of power factor leading, lagging, even unity. Have you ever thought, can the power factor be zero? And in which condition? Today we will discuss the zero power factor. First, we will discuss the definition. But we will discuss this in a different way. How about romantically? Voltage and current are like a romantic couple. They always want to stay close. And their closeness will increase the power factor. That's why we try to decrease their distance by PFI panel.- Advertisement - And if this couple (voltage and current) stays far from each other, it increases the phase angle between them and decreases the power factor. And your company will also face loss. And if they are in the same phase it would be great. Power factor will go to unity. Power Factor If we say generally, the cosine value of the angle between current and voltage is the power factor. The power factor indicates the percentage of electricity we need. The power factor's value is 0-1. The power factor is indicated by cosθ and θ is the angle between voltage and current. If the angle increases, the power factor decreases. And when the angle decreases, the power factor increases. Theoretically, the power factor can be zero. If your used load is Pure inductive/capacitive then the power factor can be zero. - Advertisement - We know current stays at 90° with voltage in pure inductive load. And if we put the value in the power factor equation we will get a zero. What is this condition? This condition indicates there is reactive power all over the system. That means there is no real power. Power Factor = Real Power/Apparent Power As real power is zero power factor is also zero. There is no such power system where is no real power. If a motor is an inductive load its rotor will rotate by real power. If you think hypothetically, the motor will completely shut down if there is no real power. The power system will be ruined for reactive components. We know, I= P/cosΦ Motor It means if the power factor is zero it will take infinite current. So the chances of a short circuit are also high. That was all for today's article 'what is the zero power factor?' I hope, now you understood the zero power factor. If you want to ask any questions, you can ask in the comment section. You can also read: What Is The Difference Between AIS and GIS Substations? Page 2Character descriptionMiddle SchoolGeneral StudiesOtherDescribing a character involves detailing their physical attributes, personality traits, motivations, and actions to create a vivid image in the reader's mind.Page 3Synthetic DivisionHigh SchoolMathAlgebraSynthetic division is a shortcut method for polynomial division when dividing by a linear factor of the form (x-c). It simplifies the process by using only the coefficients of the dividend and the constant term of the divisor.Page 4Permanent differenceUndergraduateBusinessAccountingA permanent difference is a difference between financial statement income and taxable income that will not reverse in future periods. It is not included in deferred tax calculations.Page 5Social conceptsHigh SchoolArts & HumanitiesHistoryThese terms represent significant historical and social concepts. Inflation refers to a general increase in prices. The Great Depression was a severe worldwide economic downturn. Discrimination involves unfair treatment based on prejudice. Democracy is a system of government by the people. Hyperinflation is extremely rapid inflation. Genocide is the systematic killing of a group of people. Extermination is the act of destroying something completely.Page 6Page 7Page 8Greenhouse gas emissionsHigh SchoolScienceEnvironmental ScienceAutomobile exhaust releases gases like CO2, contributing to global warming and climate change.Page 9Two-point formHigh SchoolMathAlgebraThe two-point form is a method to find the equation of a line given two points. The formula is (y - y1) = m(x - x1), where m is the slope and (x1, y1) is one of the points.Page 10Prepositions of TimeElementary SchoolLanguageEnglishPrepositions of time (in, on, at) are used to show when something happens. 'In' is used for longer periods (years, months, seasons); 'On' is used for days and dates; 'At' is used for specific times.Page 11Page 12Page 13Similar TrianglesHigh SchoolMathGeometrySimilar triangles have the same shape, with corresponding angles being equal and corresponding sides being proportional.Page 14Negative ExponentMiddle SchoolMathAlgebraA negative exponent indicates the reciprocal of the base raised to the positive exponent. For example, x⁻ⁿ = 1/xⁿ.Page 15Trigonometric ratiosHigh SchoolMathTrigonometryTrigonometric ratios (sin, cos, tan) relate angles of a right-angled triangle to the ratio of its sides. They are used to solve problems involving angles and distances.Page 16Cause and EffectElementary SchoolGeneral StudiesOtherIdentifying the cause and effect relationship between events.Page 17SettingMiddle SchoolGeneral StudiesOtherThe setting is where and when a story takes place. It includes the time period, geographical location, and social environment.Page 18AnalogyMiddle SchoolGeneral StudiesOtherAnalogies test the student's ability to identify relationships between words and apply that relationship to find a corresponding word pair.Page 19LibreOffice WriterMiddle SchoolScienceComputer ScienceLibreOffice Writer is a word processor. The question tests the student's ability to identify the functions of different icons within the program.Page 20VocabularyElementary SchoolGeneral StudiesOtherFill in the blanks with appropriate words to complete the sentences.Page 21Technological toolsElementary SchoolGeneral StudiesOtherTechnology refers to the application of scientific knowledge for practical purposes. It encompasses tools, machines, materials, and processes used to solve problems and improve lives.Page 22Percent changeMiddle SchoolMathStatistics & ProbabilityPercent change is the difference between the old and new values, divided by the old value, and multiplied by 100%.Page 23Circle propertiesElementary SchoolMathGeometryCircles are round shapes with all points equidistant from the center. Key properties include radius, diameter, circumference, and area.Page 24Average calculationUndergraduateMathStatistics & ProbabilityThe average is calculated by summing up all values and dividing by the count of values.Page 25Page 26Median wage High SchoolMathStatistics & ProbabilityThe median is the middle value in a dataset that is ordered from least to greatest. If there's an even number of data points, the median is the average of the two middle values. This Zero power factor (ZPF) method is used to determine the voltage regulation of synchronous generator or alternator. This method is also called Potier method. In the operation of an alternator, the armature resistance drop IRa and armature leakage reactance drop IXL are actually emf quantities while the armature reaction is basically MMF quantity. In the synchronous Impedance, all the quantities are treated as EMF quantities as against this in MMF method all are treated as MMF quantities. Key Point: This zpf method is based on the separation of armature leakage reactance and armature reaction effects. The armature leakage reactance XL is called Potier reactance in this method, hence ZPF method is also called Potier reactance method. Must Read: Principle and working of Synchronous generator or alternator To determine armature leakage reactance and armature reaction MMF separately two tests are performed on the alternator. The two tests are 1. Open circuit test 2. Zero power factor test 1.Open circuit test: The below is the block diagram to perform open circuit test on the alternator. Open circuit test is done step by step from the following points, 1. The switch S is opened. 2. The alternator is made to rotate using prime mover at synchronous speed and same speed is maintained constant throughout the test. 3. The excitation value is changed using a potential divider, from zero up to the rated value in a definite number of steps. The open circuit EMF is measured with the help of voltmeter. The readings are tabulated. 4. A graph of If and (Voc)ph i.e. field current and open circuit voltage per phase is plotted to some scale. This is open circuit characteristics. 2.Zero power factor test: To conduct zero power factor test, the switch S is kept closed. Due to this, a purely inductive load gets connected to an alternator through an ammeter. A purely inductive load has a power factor of cos 90° i.e. zero lagging hence the test is called zero power factor test. The machine speed is maintained constant at its synchronous value. The load current delivered by an alternator to purely inductive load is maintained constant at its rated full load value by varying excitation and by adjusting variable inductance of the inductive load. Note that, due to purely inductive load, an alternator will always operate at zero power factor lagging. Key Point: In this test, there is no need to obtain a number of points to obtain the curve. Only two points are enough to construct a curve called zero power factor saturation curve. Below is the graph of terminal voltage against excitation when delivering full load zero power factor current. One point for this curve is zero terminal voltage (short circuit condition) and the field current required to deliver full load short circuit armature current. While other point is the field current required to obtain rated terminal voltage while delivering rated full load armature current. With the help of these two points, the zero power factor saturation curve can be obtained as 1. Plot open circuit characteristics on a graph paper as shown in the below figure. 2. Plot the excitation corresponding to zero terminal voltage i.e. short circuit full zero power factor armature current. This point is shown as A in the below figure which the x-axis. Another point is the rated voltage when the alternator is delivering full current at zero p.f. This point is P as shown in the below figure. 3. Draw the tangent to O.C.C. through origin which is line OB as shown dotted in below figure. This is called the airline. 4. Draw the horizontal line PQ parallel and equal to OA. 5. From the point, Q draw the line parallel to the airline which intersects O.C.C. at point R. Join RQ and join PR. The triangle PQR is called Potier triangle. 6. From point R, drop a perpendicular on PQ to meet at point S. 7. The zero power factor full load saturation curve is now be constructed by moving triangle PQR so that R remains always on OCC and line PQ always remains horizontal. The dotted curve in the above figure shows it. 8.Though point A, draw a line parallel to PR meeting OCC at point B. From B, draw a perpendicular on OA to meet it at point C. Triangles OAB and PQR are similar triangles. 9. The perpendicular RS gives the voltage drop due to the leakage reactance i.e. IXL 10. The length PS gives the field current necessary to overcome the demagnetising effect of armature reaction at full load. 11. The length SQ represents field current required to induce an EMF for balancing leakage reactance drop RS. These values can be obtained from any Potier triangle such as OAB, PQR and so on. So armature leakage reactance can be obtained as, This is nothing but the Potier reactance. To determine regulation using Potier reactance, the phasor diagram using the following procedure: 1. Take the rated terminal voltage Vph as a reference phasor. Depending upon at which power factor (cos Φ) the regulation is to be predicted, draw the current phasor Iph lagging or leading Vph by angle Φ. 2. Draw Iph Raph voltage drop to Vph which is in phase with Iph. While the voltage drop Iph XLph is to be drawn perpendicular to Iph Raph vector but leading Iph Raph at the extremity of Vph. 3. The Rph is to be measured separately by passing a d.c current and measuring the voltage across armature winding. While XLph is Potier reactance obtained by Potier method. Phasor sum of Vph rated, Iph Raph and Iph XLph gives the e.m.f. which is say E1ph. E1ph = Vph +Iph Raph +Iph XLph 4. Obtain the excitation corresponding to E1ph from OCC which is drawn. Let this excitation be Ff1. This is excitation required for inducing EMF which does not consider effect of armature reaction. 5. The field current required to balance the armature reaction can be obtained from Potier triangle method, which is say FAR. FAR = I (PS) = I (AC) .... 6. The total excitation required is the vector sum of the Ff1 and FAR. This can be obtained exactly similar to the procedure used in MMF method. 7. Draw vector Ff1 to some scale, leading E1ph by 90°. Add FAR to Ff1 by drawing vector FAR in phase opposition to Iph. The total excitation to be supplied by field is given by FR. The complete phasor diagram is shown in the below figure. Once the total excitation is known which is FR, the corresponding induced EMF Eph can be obtained from OCC. This Eph lags FR by 90°. The length CD gives the armature current phasor meeting at points G and H respectively, we get triangle OHC as right-angle triangle. Hence E1ph can be determined, analytically also. Once Eph is known, the regulation of an alternator can be predicted as, ZPF method takes into consideration the armature resistance and leakage reactance voltage drops as EMF quantities and the effect of armature reaction as MMF quantity. This is the reality hence the results obtained by this method are nearer to the reality than those obtained by synchronous impedance method and ampere-turns method. The only drawback of the ZPF method is that the separate curve for every load condition is necessary to plot if Potier triangles for various load conditions are required. Some assumptions are made in the Potier method which is listed below 1.In the entire calculation procedure of Potier method, the armature resistance is neglected. But practically armature resistance is very small and hence this assumption does not cause significant error in the accuracy. 2. In Potier method, a zero power factor test is required to be done. But practically when inductors are used, a perfect zero power factor cannot be achieved. 3. Consider the graphical interpretation of Potier method shown in the below figure. In this graph, the distances RS, R' S' and BC are assumed equal. This represents the voltage drop across the leakage reactance which is (Iaph)FL * XLph.This indicates that the point P in the zero power factor method and point A in the short circuit test represent the same leakage reactance of the machine. But this is not true as the excitation under short circuit condition is OA while that for point P is OA as shown. Now the excitation OA' is much higher than OC and hence point P corresponding to saturated conditions represents larger leakage flux which in the method assumed unchanged. Hence practically the leakage flux corresponding to saturated conditions is higher than that assumed in the method. This introduces the error in the calculations. Now today we have learnt Zero power factor(ZPF) or Potier triangle method for regulation of alternator. You can download this article as pdf, ppt. Comment below for any Queries. Synchronising Power is defined as the difference between input power to alternator at power angle and input power to alternator at power angle + '.Synchronizing Power is denoted by PSY. Consider an alternator connected to the infinite bus bar. Let V be the bus bar voltage and E be the EMF induced in the alternator. The excitation of the alternator is adjusted in such a way that E and V are equal in magnitude. In the local circuit, the two voltages E and V are in phase opposition while in the external circuit they are in the same phase. This is represented in the below figure. Must Read: Principle and working of Synchronous generator or alternator Consider the alternator to be at no load. If by some means power input to the machine is decreased and it's induced EMF E will then lag behind V by say angle 2.Due to this difference, E and V will not remain in exact phase opposition but will give rise to resultant EMF Er.This ER will act in the local circuit and a synchronizing current will start flowing in the local circuit.The synchronizing current is given by, ISY = Er/Zs Isy is lagging behind Er by an angle θ given by θ = tan⁻¹(Xs/R) R is very very small hence it can be neglected. θ = 90° The angle 2 is very small and θ is approximately equal to 90° so the synchronizing current Isy is almost in phase with V and in phase opposition with E.So infinite bus bar will deliver some power to the alternator. As the current in the local circuit is always opposing to induced EMF E, the alternator will act as a synchronous motor. Thus synchronizing torque will be developed which will try to accelerate the machine. Hence the angle 2 will go on decreasing and resultant EMF Er also goes on decreasing. Finally, the two EMF's E and V will again be in phase opposition and the machine will now act as an alternator to infinite bus bar. Thus the power which automatically comes into play and accelerates the machine which was retarding and decelerates the machine which tries to accelerate is called synchronizing power. This power will keep the machine in step with the infinite bus bar. This textbook "Electrical Machinery by P.S. Bhimbhra" is the best in industry. Grab it now for very less price. Consider an alternator which is operating at a power angle i.e. E leads V by an angle . Let power input of this alternator be increased suddenly so that it will now operate at a new power angle given by + '.So the synchronizing emf ESY will come into play and sends a circulating current given by ISY = ESY/Zs. This current produces synchronizing power. Now we will derive the expression for synchronizing power per phase. Before increasing the input of alternator, the power input Pi1 is given by, When power angle has changed to ±' (+ sign indicates acceleration and – sign indicates deceleration) the power input Pi2 is given by The difference between these two powers is nothing but synchronizing power PSY. PSY = Pi2 – Pi1 If ′ is small then ′/2 is very very small. Therefore sin²(′/2) can be neglected as it is tending towards zero. For large synchronous machines θ = 90° and Zs = Xs as Ra is neglected For synchronous generator which is synchronized with bus bar V = E, = 0 and ′ is very very small. Sin ′ = ′ and Cos = 1 The above expression is per phase power. Therefore for the machine having 'm' phases the synchronizing power is given by, The same expression is not valid for salient pole machine. The expression for salient pole machine can be obtained as follows: From figure(a), it can be observed that From figure(b), it can be observed that Must Read: Zero power factor or Potier triangle method for regulation of alternator Thus the total power consists of a fundamental component and a second harmonic component which is present because the armature reaction flux has a tendency to pass through the field structure along its minimum reluctance path i.e. along field pole axis and direct axis. Since 2 exists because of difference in reluctance along p and q axes and is called reluctance power and the term is called reluctance torque. The first term is identical with that obtained for the cylindrical machine and component of power is known as electromagnetic power.

Now dP/d gives the Synchronizing power. Conclusion: Now today we have learnt about Synchronizing Power and also derived the expression for Synchronizing Power for salient pole machine. You can download this article as pdf, ppt. Comment below for any Queries. JavaScript is disabled in your browser. Please enable JavaScript to proceed. Power factor is an expression of energy efficiency. It is usually expressed as a percentage—and the lower the percentage, the less efficient power usage is.Power Factor (PF) is the ratio of working power, measured in kilowatts (kW), to apparent power, measured in kilovolt amperes (kVA). Apparent power, also known as demand, measures the amount of power used to run machinery and equipment during a certain period. It is found by multiplying voltage (V) by current (A). The result is expressed as kVA units.kVA = V x APF expresses the ratio of true power used in a circuit to the apparent power delivered to the circuit. A 96% power factor demonstrates more efficiency than a 75% power factor. PF below 95% is considered inefficient in many regions.PF expresses the ratio of true power used in a circuit to the apparent power delivered to the circuit. A 96% power factor demonstrates more efficiency than a 75% power factor. PF below 95% is considered inefficient in many regions.Understanding the Electric Power FormulaUnderstanding the electric power formula will help teams increase efficiency and make better, more informed decisions about the use of electrical energy.The electrical power formula is:P = V x IIn this equation, I is the electrical current, V is the voltage, and P is the total electrical power.The power formula expresses the amount of real power that is delivered by devices. This makes it crucial for understanding exactly how electrical energy is consumed and measured in electrical systems.Understanding the electric power formula also gives users the foundation for grasping what real power means. That's a crucial step toward understanding why the power factor, which relates to the ratio of real power to apparent power, is so important.It's a best practice to first make sure your teams have a solid understanding of the electric power formula before moving on to the power factor formula. Following this order ensures that teams can easily grasp how electrical measurements relate to real power. It also ensures they fully understand the connections between voltage, current, and power before they attempt to calculate power factor.How to Make Sense of Power FactorUnderstanding power factor can be a complex concept, but it can be simplified with a relatable analogy. Imagine a glass of beer. In this analogy, different parts of the beer and the glass represent different types of power in an electrical system.Beer is active power (kW) — the liquid beer is useful power. This is the energy doing the work, which is the part you want.Foam is reactive power (kVAR) — the foam is wasted power or lost power. It's the energy being produced that isn't doing any work (such as heat or vibrations).The mug is apparent power (kVA) — the mug is the demand power, or the power being delivered by the utility.If a circuit were 100% efficient, demand would equal the power available. But when demand is greater than the power available, a strain is placed on the utility system. Many utilities add a demand charge to the bills of large customers to offset differences between supply and demand (where supply is lower than demand). For most utilities, demand is calculated based on the average load placed within 15 to 30 minutes. If demand requirements are irregular, the utility must have more reserve capacity available than if load requirements remain constant.Peak demand is when demand is at its highest. The challenge for utilities is delivering power to handle every customer's peaks. Using power at the moment it's in highest demand can disrupt overall supply, unless there are enough reserves. Therefore, utilities bill for peak demand. For some larger customers, utilities might even take the highest demand and apply it across the full billing period.Utilities apply surcharges to companies with a lower power factor. The costs of lower efficiency can be steep — akin to driving a gas-guzzling car. The lower the power factor, the less efficient the circuit, and the higher the overall operating cost. The higher the operating cost, the higher the likelihood that utilities will penalize a customer for overutilization. In most Alternating Current (AC) circuits, there is never power factor equal to one because there is always some impedance (interference) in the power lines.How to Calculate Power FactorTo calculate power factor, you need a power quality analyzer or power analyzer that measures both working power (kW) and apparent power (kVA). With this data, you can calculate the ratio of kW/kVA.Power Factor FormulaThe power factor formula can be expressed in multiple ways. For example:PF = (True power)/(Apparent power)orPF = W/VAIn the second equation, W is a measure of useful power, while VA is a measure of supplied power. The ratio of the two is essentially useful power to supplied power, or:As this diagram demonstrates, power factor compares the real power (or power available to perform work) being consumed to the apparent power, or demand of the load. You can avoid power factor penalties by improving power factor.Poor power factor means that you're using power inefficiently. This matters to companies because it can result in:Heat damage to insulation and other circuit componentsReduction in the amount of available useful powerA required increase in conductor and equipment sizesFinally, a low power factor increases the overall cost of a power distribution system because it requires a higher current to supply loads.By understanding and improving power factor, companies can achieve significant cost savings and enhance the efficiency of their electrical systems. Investing in power quality analyzers and implementing power factor correction measures can lead to lower utility bills and reduced strain on the electrical infrastructure. Ratio of active power to apparent power For the firearms cartridge ranking system, see Power factor (shooting sports). In electrical engineering, the power factor of an AC power system is defined as the ratio of the real power absorbed by the load to the apparent power flowing in the circuit. Real power is the average of the instantaneous product of voltage and current and represents the capacity of the electricity for performing work. Apparent power is the product of root mean square (RMS) current and voltage. Due to energy stored in the load and returned to the source, or due to a non-linear load that distorts the wave shape of the current drawn from the source, the apparent power may be greater than the real power, so more current flows in the circuit than would be required to transfer real power alone. A power factor magnitude of less than one indicates the voltage and current are not in phase, reducing the average product of the two. A negative power factor occurs when the device (normally the load) generates real power, which then flows back towards the source. In an electric power system, a load with a low power factor draws more current than a load with a high power factor for the same amount of useful power transferred. The larger currents increase the energy lost in the distribution system and require larger wires and other equipment. Because of the costs of larger equipment and wasted energy, electrical utilities will usually charge a higher cost to industrial or commercial customers with a low power factor. Power-factor correction increases the power factor of a load, improving efficiency for the distribution system to which it is attached. Linear loads with a low power factor (such as induction motors) can be corrected with a passive network of capacitors or inductors. Non-linear loads, such as rectifiers, distort the current drawn from the system. In such cases, active or passive power factor correction may be used to counteract the distortion and raise the power factor. The devices for correction of the power factor may be at a central substation, spread out over a distribution system, or built into power-consuming equipment. Schematic showing how power factor is calculated The general expression for power factor is given by power factor = P / P a {\displaystyle {\mbox{power factor}}=P/P_{a}} P a = I r m s V r m s {\displaystyle P_{a}=I_{rms}V_{rms}} where P {\displaystyle P} is the real power measured by an ideal wattmeter, I r m s {\displaystyle I_{rms}} is the rms current measured by an ideal ammeter, and V r m s {\displaystyle V_{rms}} is the rms voltage measured by an ideal voltmeter. Apparent power, P a {\displaystyle P_{a}} , is the product of the rms current and the rms voltage. If the load is sourcing power back toward the generator, then P {\displaystyle P} and power factor {\displaystyle {\mbox{power factor}}} will be negative. If the waveforms are periodic with the same fundamental period, then the power factor can be computed as follows: P = 1 T ∫ t ′ t ′ + T i (t) v (t) d t , I r m s = 1 T ∫ t ′ t ′ + T i (t) 2 d t , V r m s = 1 T ∫ t ′ t ′ + T v (t) 2 d t , power factor = P I r m s V r m s , {\displaystyle {\begin{aligned}P&={\frac {1}{T}}\int _{t'}^{t'+T}i(t)v(t)dt,\\I_{rms}&={\sqrt {{\frac {1}{T}}\int _{t'}^{t'+T}{i(t)}^{2}dt}},\\V_{rms}&={\sqrt {{\frac {1}{T}}\int _{t'}^{t'+T}{v(t)}^{2}dt}},\\{\mbox{power factor}}&={\frac {P}{I_{rms}V_{rms}}},\end{aligned}}} where i (t) {\displaystyle i(t)} is the instantaneous current, v (t) {\displaystyle v(t)} is the instantaneous voltage, t ′ {\displaystyle t'} is an arbitrary starting time, and T {\displaystyle T} is the period of the waveforms. If the waveforms are not periodic and the physical meters have the same averaging time, then the equations for the periodic case can be used with the exception that T {\displaystyle T} is the averaging time of the meters instead of the waveform period. Power flow calculated from AC voltage and current entering a load having a zero power factor (ϕ = 90°, cos(ϕ) = 0). The blue line shows the instantaneous power entering the load: all of the energy received during the first (or third) quarter cycle is returned to the grid during the second (or fourth) quarter cycle, resulting in an average power flow (light blue line) of zero. Instantaneous and average power calculated from AC voltage and current for a load with a lagging power factor (ϕ = 45°, cos(ϕ) ≈ 0.71). The blue line (instantaneous power) shows that a portion of the energy received by the load is returned to the grid during the part of the cycle labeled ϕ. In a linear circuit, consisting of combinations of resistors, inductors, and capacitors, current flow has a sinusoidal response to the sinusoidal line voltage.[1] A linear load does not change the shape of the input waveform but may change the relative timing (phase) between voltage and current, due to its inductance or capacitance. In a purely resistive AC circuit, voltage and current waveforms are in step (or in phase), changing polarity at the same instant in each cycle. All the power entering the load is consumed (or dissipated). Where reactive loads are present, such as with capacitors or inductors, energy storage in the loads results in a phase difference between the current and voltage waveforms. During each cycle of the AC voltage, extra energy, in addition to any energy consumed in the load, is temporarily stored in the load in electric or magnetic fields then returned to the power grid a fraction of the period later. Electrical circuits containing predominantly resistive loads (incandescent lamps, devices using heating elements like electric toasters and ovens) have a power factor of almost 1, but circuits containing inductive or capacitive loads (electric motors, solenoid valves, transformers, fluorescent lamp ballasts, and others) can have a power factor well below 1. A circuit with a low power factor will use a greater amount of current to transfer a given quantity of real power than a circuit with a high power factor thus causing increased losses due to resistive heating in power lines, and requiring the use of higher-rated conductors and transformers. AC power has two components: Real power or active power (P {\displaystyle P}) (sometimes called average power[2]), expressed in watts (W) Reactive power (Q {\displaystyle Q}), usually expressed in reactive volt-amperes (var)[3] Together, they form the complex power (S {\displaystyle S}) expressed as volt-amperes (VA). The magnitude of the complex power is the apparent power (| S | {\displaystyle |S|}), also expressed in volt-amperes (VA). The VA and var are non-SI units dimensionally similar to the watt but are used in engineering practice instead of the watt to state what quantity is being expressed. The SI explicitly disallows using units for this purpose or as the only source of information about a physical quantity as used.[4] The power factor is defined as the ratio of real power to apparent power. As power is transferred along a transmission line, it does not consist purely of real power that can do work once transferred to the load, but rather consists of a combination of real and reactive power, called apparent power. The power factor describes the amount of real power transmitted along a transmission line relative to the total apparent power flowing in the line.[5][6] The power factor can also be computed as the cosine of the angle θ by which the current waveform lags or leads the voltage waveform.[7] One can relate the various components of AC power by using the power triangle in vector space. Real power extends horizontally in the real axis and reactive power extends in the direction of the imaginary axis. Complex power (and its magnitude, apparent power) represents a combination of both real and reactive power, and therefore can be calculated by using the vector sum of these two components. We can conclude that the mathematical relationship between these components is: S = P + j Q | S | = P 2 + Q 2 pf = cos θ = P | S | = cos (arctan (Q P)) Q = P tan (arccos (pf)) {\displaystyle {\begin{aligned}S&=P+jQ\\|S|&={\sqrt {P^{2}+Q^{2}}}\\{\text{pf}}&=\cos {\theta }={\frac {P}{|S|}}=\cos {\left(\arctan {\left({\frac {Q}{P}}\right)}\right)}\\Q&=P\,\tan(\arccos({\text{pf}}))\end{aligned}}} As the angle θ increases with fixed total apparent power, current and voltage are further out of phase with each other. Real power decreases, and reactive power increases. Power factor is described as leading if the current waveform is advanced in phase concerning voltage, or lagging when the current waveform is behind the voltage waveform. A lagging power factor signifies that the load is inductive, as the load will consume reactive power. The reactive component Q {\displaystyle Q} is positive as reactive power travels through the circuit and is consumed by the inductive load. A leading power factor signifies that the load is capacitive, as the load supplies reactive power, and therefore the reactive component Q {\displaystyle Q} is negative as reactive power is being supplied to the circuit. If θ is the phase angle between the current and voltage, then the power factor is equal to the cosine of the angle, cos θ {\displaystyle \cos \theta } : | P | = | S | cos θ {\displaystyle |P|=|S|\cos \theta } Since the units are consistent, the power factor is by definition a dimensionless number between -1 and 1. When the power factor is equal to 0, the energy flow is entirely reactive, and stored energy in the load returns to the source on each cycle. When the power factor is 1, referred to as the unity power factor, all the energy supplied by the source is consumed by the load. Power factors are usually stated as leading or lagging to show the sign of the phase angle. Capacitive loads are leading (current leads voltage), and inductive loads are lagging (current lags voltage). If a purely resistive load is connected to a power supply, current and voltage will change polarity in step, the power factor will be 1, and the electrical energy flows in a single direction across the network in each cycle. Inductive loads such as induction motors (any type of wound coil) consume reactive power with the current waveform lagging the voltage. Capacitive loads such as capacitor banks or buried cables generate reactive power with the current phase leading the voltage. Both types of loads will absorb energy during part of the AC cycle, which is stored in the device's magnetic or electric field, only to return this energy back to the source during the rest of the cycle. For example, to get 1 kW of real power, if the power factor is unity, 1 kVA of apparent power needs to be transferred (1 kW ÷ 1 = 1 kVA). At low values of power factor, more apparent power needs to be transferred to get the same real power. To get 1 kW of real power at 0.2 power factor, 5 kVA of apparent power needs to be transferred (1 kW ÷ 0.2 = 5 kVA). This apparent power must be produced and transmitted to the load and is subject to losses in the production and transmission processes. Electrical loads consuming alternating current power consume both real power and reactive power. The vector sum of real and reactive power is the complex power, and its magnitude is the apparent power. The presence of reactive power causes the real power to be less than the apparent power, and so, the electric load has a power factor of less than 1. A negative power factor (0 to −1) can result from returning active power to the source, such as in the case of a building fitted with solar panels when surplus power is fed back into the supply.[8][9][10] Power factor correction of linear load A high power factor is generally desirable in a power delivery system to reduce losses and improve voltage regulation at the load. Compensating elements near an electrical load will reduce the apparent power demand on the supply system. Power factor correction may be applied by an electric power transmission utility to improve the stability and efficiency of the network. Individual electrical customers who are charged by their utility for low power factor may install correction equipment to increase their power factor to reduce costs. Power factor correction brings the power factor of an AC power circuit closer to 1 by supplying or absorbing reactive power, adding capacitors or inductors that act to cancel the inductive or capacitive effects of the load, respectively. In the case of offsetting the inductive effect of motor loads, capacitors can be locally connected. These capacitors help to generate reactive power to meet the demand of the inductive loads. This will keep that reactive power from having to flow from the utility generator to the load. In the electricity industry, inductors are said to consume reactive power, and capacitors are said to supply it, even though reactive power is just energy moving back and forth on each AC cycle. The reactive elements in power factor correction devices can create voltage fluctuations and harmonic noise when switched on or off. They will supply or sink reactive power regardless of whether there is a corresponding load operating nearby, increasing the system's no-load losses. In the worst case, reactive elements can interact with the system and with each other to create resonant conditions, resulting in system instability and severe overvoltage fluctuations. As such, reactive elements cannot simply be applied without engineering analysis. 1. Reactive power control relay; 2. Network connection points; 3. Slow-blow fuses; 4. Inrush-limiting contactors; 5. Capacitors (single-phase or three-phase units, delta-connection); 6. Transformer (for controls and ventilation fans) An automatic power factor correction unit consists of some capacitors that are switched by means of contactors. These contactors are controlled by a regulator that measures power factor in an electrical network. Depending on the load and power factor of the network, the power factor controller will switch the necessary blocks of capacitors in steps to make sure the power factor stays above a selected value. In place of a set of switched capacitors, an unloaded synchronous motor can supply reactive power. The reactive power drawn by the synchronous motor is a function of its field excitation. It is referred to as a synchronous condenser. It is started and connected to the electrical network. It operates at a leading power factor and puts vars onto the network as required to support a system's voltage or to maintain the system power factor at a specified level. The synchronous condenser's installation and operation are identical to those of large electric motors. Its principal advantage is the ease with which the amount of correction can be adjusted; it behaves like a variable capacitor. Unlike with capacitors, the amount of reactive power furnished is proportional to voltage, not the square of voltage; this improves voltage stability on large networks. Synchronous condensers are often used in connection with high-voltage direct-current transmission projects or in large industrial plants such as steel mills. For power factor correction of high-voltage power systems or large, fluctuating industrial loads, power electronic devices such as the static VAR compensator or STATCOM are increasingly used. These systems are able to compensate sudden changes of power factor much more rapidly than contactor-switched capacitor banks and, being solid-state, require less maintenance than synchronous condensers. Examples of non-linear loads on a power system are rectifiers (such as used in a power supply), and arc discharge devices such as fluorescent lamps, electric welding machines, or arc furnaces. Because current in these systems is interrupted by a switching action, the current contains frequency components that are multiples of the power system frequency. Distortion power factor is a measure of how much the harmonic distortion of a load current decreases the average power transferred to the load. Sinusoidal voltage and non-sinusoidal current give a distortion power factor of 0.75 for this computer power supply load. In linear circuits having only sinusoidal currents and voltages of one frequency, the power factor arises only from the difference in phase between the current and voltage. This is displacement power factor.[11] Non-linear loads change the shape of the current waveform from a sine wave to some other form. Non-linear loads create harmonic currents in addition to the original (fundamental frequency) AC current. This is of importance in practical power systems that contain non-linear loads such as rectifiers, some forms of electric lighting, electric arc furnaces, welding equipment, switched-mode power supplies, variable speed drives and other devices. Filters consisting of linear capacitors and inductors can prevent harmonic currents from entering the supplying system. To measure the real power or reactive power, a wattmeter designed to work properly with non-sinusoidal currents must be used. The distortion power factor is the distortion component associated with the harmonic voltages and currents present in the system. distortion power factor = I 1 I r m s = I 1 I 1 2 + I 2 2 + I 3 2 + I 4 2 + ⋯ = 1 1 + I 2 2 + I 3 2 + I 4 2 + ⋯ I 1 2 = 1 1 + T H D i 2 {\displaystyle {\begin{aligned}{\mbox{distortion power factor}}&={\frac {I_{1}}{I_{rms}}}\\&={\frac {I_{1}}{\sqrt {I_{1}^{2}+I_{2}^{2}+I_{3}^{2}+I_{4}^{2}+\cdots }}}\\&={\frac {1}{\sqrt {1+{\frac {I_{2}^{2}+I_{3}^{2}+I_{4}^{2}+\cdots }{I_{1}^{2}}}}}}\\&={\frac {1}{\sqrt {1+THD_{i}^{2}}}}\\\end{aligned}}} THD i {\displaystyle {\mbox{THD}}_{i}} is the total harmonic distortion of the load current. T H D i = ∑ h = 2 ∞ I h 2 I 1 = I 2 2 + I 3 2 + I 4 2 + ⋯ I 1 {\displaystyle THD_{i}={\frac {\sqrt {\displaystyle \sum _{h=2}^{\infty }I_{h}^{2}}}{I_{1}}}={\frac {\sqrt {I_{2}^{2}+I_{3}^{2}+I_{4}^{2}+\cdots }}{I_{1}}}} I 1 {\displaystyle I_{1}} is the fundamental component of the current, I r m s {\displaystyle I_{rms}} is the total current, and I h {\displaystyle I_{h}} is the current on the hth harmonic; all are root mean square values (distortion power factor can also be used to describe individual order harmonics, using the corresponding current in place of total current). This definition with respect to total harmonic distortion assumes that the voltage stays undistorted (sinusoidal, without harmonics). This simplification is often a good approximation for stiff voltage sources (not being affected by changes in load downstream in the distribution network). Total harmonic distortion of typical generators from current distortion in the network is on the order of 1–2%, which can have larger scale implications but can be ignored in common practice.[12] The result when multiplied with the displacement power factor is the overall, true power factor or just power factor (PF): PF = cos φ 1 + T H D i 2 {\displaystyle {\mbox{PF}}={\frac {\cos {\varphi }}{\sqrt {1+THD_{i}^{2}}}}} In practice, the local effects of distortion current on devices in a three-phase distribution network rely on the magnitude of certain order harmonics rather than the total harmonic distortion. For example, the triplen, or zero-sequence, harmonics (3rd, 9th, 15th, etc.) have the property of being in-phase when compared line-to-line. In a delta-wye transformer, these harmonics can result in circulating currents in the delta windings and result in greater resistive heating. In a wye-configuration of a transformer, triplen harmonics will not create these currents, but they will result in a non-zero current in the neutral wire. This could overload the neutral wire in some cases and create error in kilowatt-hour metering systems and billing revenue.[13][14] The presence of current harmonics in a transformer also result in larger eddy currents in the magnetic core of the transformer. Eddy current losses generally increase as the square of the frequency, lowering the transformer's efficiency, dissipating additional heat, and reducing its service life.[15] Negative-sequence harmonics (5th, 11th, 17th, etc.) combine 120 degrees out of phase, similarly to the fundamental harmonic but in a reversed sequence. In generators and motors, these currents produce magnetic fields which oppose the rotation of the shaft and sometimes result in damaging mechanical vibrations.[16] The simplest way to control the harmonic current is to use a filter that passes current only at line frequency (50 or 60 Hz). The filter consists of capacitors or inductors and makes a non-linear device look more like a linear load. An example of passive PFC is a valley-fill circuit. A disadvantage of passive PFC is that it requires larger inductors or capacitors than an equivalent power active PFC circuit.[17][18][19] Also, in practice, passive PFC is often less effective at improving the power factor.[20][21][22][23][24] Specifications taken from the packaging of a 610 W PC power supply showing active

PFC rating Active PFC is the use of power electronics to change the waveform of current drawn by a load to improve the power factor.[25] Some types of the active PFC are buck, boost, buck-boost and synchronous condenser. Active power factor correction can be single-stage or multi-stage. In the case of a switched-mode power supply, a boost converter is inserted between the bridge rectifier and the main input capacitors. The boost converter attempts to maintain a constant voltage at its output while drawing a current that is always in phase with and at the same frequency as the line voltage. Another switched-mode converter inside the power supply produces the desired output voltage from the DC bus. This approach requires additional semiconductor switches and control electronics but permits cheaper and smaller passive components. It is frequently used in practice. For a three-phase SMPS, the Vienna rectifier configuration may be used to substantially improve the power factor. SMPSs with passive PFC can achieve power factor of about 0.7–0.75, SMPSs with active PFC, up to 0.99 power factor, while a SMPS without any power factor correction have a power factor of only about 0.55–0.65.[26] Due to their very wide input voltage range, many power supplies with active PFC can automatically adjust to operate on AC power from about 100 V (Japan) to 240 V (Europe). That feature is particularly welcome in power supplies for laptops. Dynamic power factor correction (DPFC), sometimes referred to as real-time power factor correction, is used for electrical stabilization in cases of rapid load changes (e.g. at large manufacturing sites). DPFC is useful when standard power factor correction would cause over or under correction.[27] DPFC uses semiconductor switches, typically thyristors, to quickly connect and disconnect capacitors or inductors to improve power factor. 75 MVAr capacitor bank in a 150 kV substation Capacitor bank on a utility pole in San Jose, CA, USA Power factors below 1.0 require a utility to generate more than the minimum volt-amperes necessary to supply the real power (watts). This increases generation and transmission costs. For example, if the load power factor were as low as 0.7, the apparent power would be 1.4 times the real power used by the load. Line current in the circuit would also be 1.4 times the current required at 1.0 power factor, so the losses in the circuit would be doubled (since they are proportional to the square of the current). Alternatively, all components of the system such as generators, conductors, transformers, and switchgear would be increased in size (and cost) to carry the extra current. When the power factor is close to unity, for the same kVA rating of the transformer more load current can be supplied.[28] Utilities typically charge additional costs to commercial customers who have a power factor below some limit, which is typically 0.9 to 0.95. Engineers are often interested in the power factor of a load as one of the factors that affect the efficiency of power transmission. With the rising cost of energy and concerns over the efficient delivery of power, active PFC has become more common in consumer electronics.[29] Current Energy Star guidelines for computers[30] call for a power factor of ≥ 0.9 at 100% of rated output in the PC's power supply. According to a white paper authored by Intel and the U.S. Environmental Protection Agency, PCs with internal power supplies will require the use of active power factor correction to meet the ENERGY STAR 5.0 Program Requirements for Computers.[31] In Europe, EN 61000-3-2 requires power factor correction be incorporated into consumer products. Small customers, such as households, are not usually charged for reactive power and so power factor metering equipment for such customers will not be installed. The power factor in a single-phase circuit (or balanced three-phase circuit) can be measured with the wattmeter-ammeter-voltmeter method, where the power in watts is divided by the product of measured voltage and current. The power factor of a balanced polyphase circuit is the same as that of any phase. The power factor of an unbalanced polyphase circuit is not uniquely defined. A direct reading power factor meter can be made with a moving coil meter of the electrodynamic type, carrying two perpendicular coils on the moving part of the instrument. The field of the instrument is energized by the circuit current flow. The two moving coils, A and B, are connected in parallel with the circuit load. One coil, A, will be connected through a resistor and the second coil, B, through an inductor, so that the current in coil B is delayed with respect to current in A. At unity power factor, the current in A is in phase with the circuit current, and coil A provides maximum torque, driving the instrument pointer toward the 1.0 mark on the scale. At zero power factor, the current in coil B is in phase with circuit current, and coil B provides torque to drive the pointer towards 0. At intermediate values of power factor, the torques provided by the two coils add and the pointer takes up intermediate positions.[32] Another electromechanical instrument is the polarized-vane type.[33] In this instrument a stationary field coil produces a rotating magnetic field, just like a polyphase motor. The field coils are connected either directly to polyphase voltage sources or to a phase-shifting reactor if a single-phase application. A second stationary field coil, perpendicular to the voltage coils, carries a current proportional to current in one phase of the circuit. The moving system of the instrument consists of two vanes that are magnetized by the current coil. In operation, the moving vanes take up a physical angle equivalent to the electrical angle between the voltage source and the current source. This type of instrument can be made to register for currents in both directions, giving a four-quadrant display of power factor or phase angle. Digital instruments exist that directly measure the time lag between voltage and current waveforms. Low-cost instruments of this type measure the peak of the waveforms. More sophisticated versions measure the peak of the fundamental harmonic only, thus giving a more accurate reading for phase angle on distorted waveforms. Calculating power factor from voltage and current phases is only accurate if both waveforms are sinusoidal.[34] Power Quality Analyzers, often referred to as Power Analyzers, make a digital recording of the voltage and current waveform (typically either one phase or three phase) and accurately calculate true power (watts), apparent power (VA) power factor, AC voltage, AC current, DC voltage, DC current, frequency, IEC61000-3-2/3-12 Harmonic measurement, IEC61000-3-3/3-11 flicker measurement, individual phase voltages in delta applications where there is no neutral line, total harmonic distortion, phase and amplitude of individual voltage or current harmonics, etc.[35][36] Anglophone power engineering students are advised to remember: ELI the ICE man or ELI on ICE – the voltage E, leads the current I, in an inductor L. The current I leads the voltage E in a capacitor C. Another common mnemonic is CIVIL – in a capacitor (C) the current (I) leads voltage (V), voltage (V) leads current (I) in an inductor (L). ^ Das, J. C. (2015). Power System Harmonics and Passive Filter Design. Wiley, IEEE Press. p. 2. ISBN 978-1-118-86162-2. To distinguish between linear and nonlinear loads, we may say that linear time-invariant loads are characterized so that an application of a sinusoidal voltage results in a sinusoidal flow of current. ^ Boylestad, Robert (2002-03-04). Introductory Circuit Analysis (10th ed.). Prentice Hall. p. 857. ISBN 978-0-13-097417-4. ^ "SI Units – Electricity and Magnetism". CH: International Electrotechnical Commission. Archived from the original on 2007-12-11. Retrieved 14 June 2013. ^ The International System of Units (SI) [SI brochure] (PDF). § 5.3.2 (p. 132, 40 in the PDF file): BIPM. 2006. 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Retrieved from " Zero Power Factor Characteristic (ZPFC) of a generator is a curve of the armature terminal voltage and the field current. The machine is operated with a constantly rated armature current at synchronous speed and zero lagging power factor. The Zero Power Factor Characteristic is also called as Potier Characteristic. For maintaining a very low power factor, the alternator is loaded by means of reactors or by an under excited synchronous motor. The shape of ZPFC is very much like that of the O.C.C. The phasor diagram corresponding to zero power factor lagging is shown below: In the phasor diagram shown above, the terminal voltage V is taken as the reference phasor. At zero power factor lagging, the armature current Ia lags behind V by 90 degrees. IaRa is drawn parallel to Ia and IaXaL perpendicular to Ia. Eg is the generated voltage per phase. The phasor diagram at ZPF lagging with the armature resistance Ra neglected is shown below: Where, Far is the armature reaction MMF. It is in phase with the armature current Ia. Ff is the MMF of the main field winding (field MMF). Fr is the resultant MMF. The field MMF Ff is obtained by subtracting Far from Fr so that From the above phasor diagram, it is seen that the terminal voltage V, the reactance voltage drop IaXaL, and the generated voltage Eg all are in phase. Therefore, V is practically equal to the arithmetical difference between Eg and IaXaL. The three MMF phasor Ff, Fr and Far are in phase. Their magnitudes are related by the equation shown below: The above two equations, i.e. equation (1) and (2) forms the basis for the Potier triangle. If the equation (2) is divided both sides by Tf, it is converted into its equivalent field current form. Here Tf is the effective number of turns per pole on the rotor field. Therefore, From the above equation, the sum of the resultant current and the armature reaction current gives the field current.