## Universal ac Series Motor

The universal ac series motor, so called because it “can” operate on either ac or dc supplies.

Within limits, for a given voltage and frequency, will give approximately the same performance on either ac or dc.

This requirement is/was seldom needed in Australia, but historically was very important in many overseas countries where, unlike Australia, the supply characteristics of adjacent supply authorities did (or do) vary considerably.

The variations between the various ‘Local-Council(Borough) supply authorities included not only either a dc or ac supply, but variations in voltage, frequency and the number or phases (i.e. 1, 2, or 3).

This variation in supply was a major problem in the United Kingdom (UK) prior to nationalisation of the system in 1947. Where, over the first half of the $20^{th}$ century, in excess of 100 different systems were in use.

A comparison in area and population between the UK and say Victoria will indicate the problems encountered by manufacturers, in economically producing appliances and controls to suit the various voltages (ac and dc), frequencies and phases, but also all the companies and personal who had to service, maintain and repair the various systems.

Notwithstanding, the catastrophic problems encountered by the all various UK supply authorities in linking, sharing and maintaining supply, during the aerial bombardments of both WW1 & WW2. The problems could have been greater but for the forethought of the authorities, who had foresaw the inevitable of war, and had prepared stockpiles of spare parts.

Consumers, when purchasing appliances, had to be careful and check the appliance would operate on their supply. Also, there were repercussions if they moved house to an adjacent council with different supply characteristics.

It was this environment, which historically, initiated the development and use of the universal ac series motor. Its operation characteristics allow it to operate on either ac or dc and at different voltages and frequencies

***These days***, with the adoption of a Standard Voltage & Frequency, the ***most important and useful advantage*** of the Universal ac series motor is its ***high speed characteristics***, which unlike the induction motor is not controlled by the frequency or the number of poles.

As, Power: $P = \frac{2\pi\, nT}{60}$ in watts

Where P is proportional to nT

Then, for an increase in speed the torque required to produce the same "power output" is reduced.

And as Torque: T = Fr in newton metre

Then, for a give force (F) the radius (r) can be reduced. This means that for a given "power output", the ***physical size*** of the motor can be ***reduced*** (i.e. the higher the speed the smaller the motor)

Advantages:

a. Less material used, therefore,
b. Less weight, therefore
c. Less cost, therefore
d. More power in less space, therefore,
e. Greatly more portable

This makes them ideally suitable for such appliances vacuum cleaners, food mixers and processors, and portable power tools (i.e. builder/carpenter 2kW handheld circular saw).



**Operation:**

Developed from the dc motor where there is a fixed or stationary field, instead of the "rotating magnetic field" as is required in the induction motor. The commutator insurers a stationary field on the rotating "armature" providing a constant push/pull force between the armature and field to produce a constant torque.

From the above diagrams where the armature and field polarities have been indicated, it can be seen that with reference to (a) the direction of the rotation will only change if the direction of one of the fluxes is changed,

(b) armature flux reversed, or
(c) field flux reversed.

Note: (d) where both armature and field fluxes are reversed the direction of rotation is not changed. Therefore, it can be concluded that if the supply is reversed the direction of rotation will remain the same (or constant). Therefore if the motor is connected to an alternating supply the motor "should" still work. In theory then a dc motor "should" work on an alternating current supply.

**Shunt connected dc motor:**
(i.e. armature and field connected in parallel)

As the armature winding and field winding form separate branches of a parallel circuit and their impedances are greatly different (i.e. highly inductive field winding and relatively low inductive armature winding) it follows that there is a large differential phase angle between their currents and consequently the flux are not reversing at the same time. Therefore, the motor will not perform satisfactorily.

Historically the problems associated with running a shunt wound dc motor on alternating current were persisted with and the motor modified and modified and in fact became the forebear of the single phase induction motor.

**Series connected dc motor:**
(i.e. armature and field connected in series)

In the series motor the field winding is connected in series with the armature. Its impedance must be minimal so as not to limit the armature current yet still retain the desired ampere turns to maintain the field flux. This is achieved by decreasing the number of turns and increasing the current. As a result of these changes the field inductance is greatly reduced and it more closely matches the armature impedance. As the two windings are now connected in series their currents are in phase and when connected to an alternating current (ac) their fluxes will be reversed at the same time. As a result the direction of armature rotation will not change The next problem was the iron circuit, which in a dc motor can be of solid iron construction. However, when ac is applied eddy currents are induced and excessive heating will occure. By laminating the field iron circuit a very satisfactory ac operation can be obtained (note: as the armature must be laminated for operation on dc no change is required for ac operation).

Performance is however slightly below the dc level due to a reactance volt drop in the windings. The reactance loss is a function of the flux and turns in the armature and field windings, and the frequency. The performance deteriorates as the frequency increases, due to increased reactance in the windings. Thus, 60 hertz is the accepted upper limit for practical design purposes. The reactance loss is somewhat overcome by reducing the number of field turns, within limits, otherwise commutation problems increase. Also during commutation the armature coil undergoing commutation is short circuited by the brushes. The coil acts a transformer secondary winding, which produces heat and bad commutation. This is somewhat overcome by inserting high resistance into the closed loop, to limit the circulating current, by using high resistance brushes. This point highlights one of the many reasons why brushes must not be haphazardly changed with any available brush which happens to fit in the brush holder.

The brushes are designed and proven by life testing for each motor and its application. Commutation arcing (or sparking) between the brush and commutator will cause commutator and brush wear (by burning). Also brush bounce is a problem which can be overcome by increasing the spring tension on the brush, however, this in turn increases brush wear. If brush hardness is increased to overcome brush wear, commutator wear is increased. If the brush is too soft then carbon dust will accumulate inside the motor which may cause a short circuit and premature motor failure. Therefore, it must be emphasized, that the manufacturer has gone to a lot of trouble to select a brush which will give optimum performance characteristics. Given wear must occur it is preferable that the brush wears first as it is readily replaceable in the field.

A major disadvantage of universal motors is their bad radio interference characteristic, due to the commutator. The problem can be reduced by suitable filters.

Universal motors (also called ac series motors) develop a high torque at start or low speed and the torque decreases as the speed increases. This characteristic is ideal for portable electric drills. As twist drills are designed to cut at constant surface speeds (i.e. increase diameter, increase torque, and decrease speed).

Reversing: In theory universal motors, like dc motors, should be reversible by simply reversing the field or armature connections. However, in practice, the universal motor like the dc motor develops armature reaction. In some universal motors this problem is countered by the use of compensating winding, this type of motor is outside the scope of this course. In the majority of universal motors the brush position is fixed and the field distortion due to armature reaction is compensated for by either designing the fixed brush position to be at some fixed angle behind the neutral position and/or advancing the coil leads on the armature. It must be remembered that the armature reaction is a function of the load thus the actual optimum position of the neutral axis may vary slightly from application to application. The result in practice being that if the motor is reversed in the field very poor performance will be achieved, along with bad commutation, excessive brush and commutator wear.

**Speed control:**

Common methods being:

a. Mechanical governor;
b. Electrical governor, where the governor opens a switch which is short circuiting resistance in series with motor
c. Rheostatic
    i. Variable resistance in series
    ii. Parallel diverter:
    Variable resistance in parallel with armature. Sometimes used in preference to (i) as it gives better starting torque and more steady control. Note; field flux max. and fixed, therefore used to reduce speed.
    iii. Series diverter:
    Variable resistance in parallel with series field similar to (ii) but, armature current max. and fixed therefore used to increase speed.

d. Diode control, commonly used on hand held portable hair dryers, the diode being shorted by a switch for high speed and on low speed the switch is opened so that half wave dc is supplied to the motor (i.e. half voltage) therefore the motor runs at half speed. Also the motor used in these 240 volt appliances is only a 12 or 24 volt motor, the bulk of the voltage being dropped across the main heating element which is in series with the extra low voltage motor.
e. Triac control, a recent addition now commonly found on many power tools. The control variable resistor (or potentiometer) being the trigger switch. This method of speed control permits speed control with constant torque. Also the method is very energy efficient.

References: AS 3115, AS 3300, AS 1360.11

Electrical Circuits and Machines
A. Mychael
2nd edition

Notes:

Protection: refer AS 3115, AS 3300

Temperature Rise:
(definition)

The difference in temperature between an electrical machine, after it has been on load for some time, and the surrounding air. It is a measure of the machines capacity for dissipating the heat generated by the electrical power losses in the machine, and thus forms part of the electrical specification.

Inferred Zero Method (refer Mychael, page 23)

Equation:

Temperature Rise: $T = [ \frac{Rf}{Ri} ( 234.5 + t_i ) ] – [ 234.5 + t_f ]$

Where:
T = temperature rise in degree centigrade
$R_f$ = final resistance in ohms (refer following notes).
$R_i$ = initial resistance in ohms
234.5 = inferred zero of copper (constant)
refer AS 1360.11
copper = 235
aluminum = 228
$t_i$ = initial ambient temperature in degree centigrade
$t_f$ = final ambient temperature in degree centigrade

Ambient Temperature
(definition)

The temperature of the air or water which coming into contact with the heated parts of a machine, carries off heat. Ambient temperature is commonly known as “room temperature” in connection with air cooled apparatus not provided with artificial ventilation.

Inferred Zero:
(definition)

The point at which the Resistance/Temperature Characteristic would cut the Temperature abscissa (‘x’ co-ordinate) at zero ohms if extended linearly. The point varies from metal to metal with the slope of the characteristic.
Note:
Absolute zero (0 degrees Kelvin) = -273.15 degree centigrade.

Temperature Coefficient of Resistance Method:

Equation:

$Rh = R_c\ [1+(t_h-t_c)]$ in ohms

Where

Temperature coefficient, alpha ($\alpha$), is only valid at a specific temperature. Tables usually give value at 0, 15 or 20 degrees centigrade.

Resistance Final:
As sometime must elapse between the operations of disconnecting the motor from supply and reconnecting it to the resistance measuring device there will be a heat loss to the atmosphere and a corresponding change in winding temperature and resistance. In practice this problem is overcome by taking a series of resistance measurements at recorded time intervals from the instant of motor switch off. If the first measurement is made within 15 seconds of de-energizing the machine, this is taken as the final reading. If taken between 15 – 30 seconds, not less than four readings at 15 second intervals are to be taken and graphed. If not made within 30 seconds the test is invalid. The values are then graphed (Resistance to Time) and the characteristic is then extrapolated back to zero time to estimate the winding resistance at the instant of switch off. Note: there are circuits which enable on load resistance measurements to be taken.

Insulation classes:

| | |
|---|---|
| Class O. | 90 degrees centigrade maximum |
| Class A. | 105 degrees centigrade maximum |
| Class E. | 120 degrees centigrade maximum |
| Class B. | 130 degrees centigrade maximum |
| Class F. | 155 degrees centigrade maximum |
| Class H. | 180 degrees centigrade maximum |
| Class C. | over 180 degrees centigrade |