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PROCEDURE TO CHANGE THE DIRECTION OF ROTATION OF DUAL WINDING SYNCHRONOUS MOTOR "AC ELECTRIC DRIVE SYSTEM"

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Abstract

In some of the power plants , dual windings synchronous motors are used in Induced Drafts (ID) Fans for which Variable Voltage and Variable Frequency Drive (VVVFD) is used for smooth speed control at different operating loads. Dual Winding Synchronous Motor is a motor with two stator windings on same stator with 300magnetically apart construction, and fed by high electrical voltage (2 to 4 KV) from dual HV sources having vector difference of 30 deg available due to (Dd0) and (Dyn1) vector group transformers. One of the dual winding is fed from Ddo transformer and another winding is fed from Dyn1 Transformer through VVFD system mounted with several racks of thyristors. The compensation of these vector group will be done at VVFD Panel controllers for smooth firing of the thyristors without any overlapping during conduction from both HV sources. The direction of rotation of motor from both windings must be uniform/in same direction. So during initial startup of motor from each winding the direction of rotation to be checked one by one. In case of opposite direction of rotation with any one of the winding, special care to be taken for interchanging any two terminals of winding through which the direction of rotation is found reverese/opposite. This article will guide and comes out with the procedure for changing the direction of rotation of dual winding synchronous motor, when the direction with any winding is found in opposite w.r.t other.

1. Introduction

The speed control in a very smooth manner is required now a day in most of the industrial and domestic utility applications. Various systems were developed to get the required speed and smooth controls of the motion, the systems are so called Drives. Basically drives require diesel or petrol engines, gas or steam turbines or electric motors. These drives deliver the required mechanical energy for getting the motion and its control. Drives employing Electric motors as prime movers for motion control are called Electric Drives. Electric drives are of two types: DC Drives and AC Drives, DC motors are used extensively in adjustable speed drives and position control applications. The speed below base speed can be controlled by armature voltage control and the speed above base speed is obtained by field flux control. As speed control methods for DC motors are simpler and less expensive than those for AC motors, DC Motors are preferred where wide speed range is required.

1.1. Types of Drives DC Drives and AC Drives

In DC drives, basically there are two methods of speed control,

- Armature Voltage Control (AVC)
- Flux Control (FC)

1.2 Important features of DC Motor Speed Control:

Armature voltage control (AVC) is preferred because of high efficiency, good transient response, and good speed regulation. But it can provide speed control below base speed only because armature voltage cannot exceed the rated value.

AVC is achieved by single and three phase Semi & Full converters.

Field Control in separately excited motors is obtained by varying the voltage across the field winding and in series motors by varying the number of turns in the field winding or by connecting a diverting resistance across the field winding.

Due to the maximum torque and power limitations, DC drives operating, with full field; AVC below base speed can deliver a constant maximum torque. This is because in AVC with full field, the Torque is proportional to Ia and consequently the torque that the motor can deliver has a maximum value.

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With rated Armature Voltage, Flux control above base speed can deliver a constant maximum power. This is because at rated armature voltage, Pm is proportional to Ia and consequently the maximum power that can be developed by the motor has a constant value.

In AC drives, basically there are two drives,

1. Induction Motor Drives

2. Synchronous Motor Drives.

There phase induction motors are commonly employed in adjustable speed drives than three phase syncrononous motors.Three phase inducton motors are of two types. Squirrel Cage Induction Motors (SCIMs) and Slip Ring induction motors (SRIMs).The advantages of AC drives outweigh their disadvantages due to vide industrial applications.

Various type of Speed Control in AC Drives.

Stator Voltage Control

Stator Frequency Control

Stator Voltage and Frequency Control (V/f method)

2. Advantages of Electric Drives:

Electric motors have high efficiency, low losses, and considerable overloading capability. They have longer life, lower noise and lower maintenance requirements.

Efficient Starting /Braking is possible with simple control gear.

With the rapid development in the field of Power Electronics and availability of high speed/high power devices like SCRs, Power MOSFETs, IGBTs etc., design of Efficient Power Converters to feed power to the electric drives has become simple and easy.

They are powered from electrical energy which can be easily transferred, stored and handled.

The Torque speed characteristics of the motor can be very easily modified to suit the load characteristics.

An electric motor can operate in all the four quadrants of V-I Plane, corresponding to the mechanical quantities speed and torque.

No hazardous chemical or fuel is required, No exhaust gasses are emitted to pollute the environment. The noise level is also low.

2.1 Selection Factors for Electrical Drives:

2.1.1. Steady State Operation Requirements:

Nature of speed-torque characteristics, speed regulation, speed range, efficiency, duty cycle, quadrants of operation, speed fluctuations.

2.1.2. Transient Operation Requirements:

Value of acceleration and de-acceleration, starting braking and reversing performance.

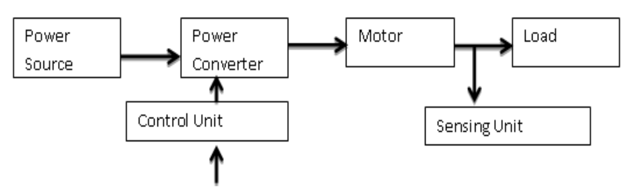
2.1.3. Requirement related to source:

Type of source, magnitude of source voltage, voltage fluctuation, power factor and harmonics.

2.1.4. Other Factors:

Capital and running cost maintenance needs, life, space and weight restriction, environment and location , reliability

2.2 Block Diagram of Electrical Drive



2.3 Parts of an Electric Drive:

The different parts &their functions are explained here.

2.3.1 The load: Can be any one of the systems like pumps, machines etc. to carry out specific task. Usually the load requirements are specified in terms of its speed/torque demands. An electrical motor having the torque speed characteristics compatible to that of the load has to be chosen.

2.3.2 Power Converter:

- It converts electrical energy from the source into a form suitable to the motor. Say AC to DC for a DC motor and DC to AC for an Induction motor.
- Controls the flow of power to the motor so as to get the Torque Speed characteristics as required by the load.
- During transient operations such as Starting, Braking, Speed reversal etc. limits the currents to permissible levels to avoid conditions such as Voltage dips, Overloads etc.
- Selects the mode of operation of the Motor i.e. Motoring or Braking.

2.3.3 Types of Power Converters:

- There are several types of power converters depending upon the type of motor used in a given drive. A brief outline of a few important types is given below.
- AC to DC converters: They convert single phase/Poly phase AC supply into fixed or variable DC supply using either simple rectifier circuits or controlled rectifiers with devices like thyristors, IGBTs. Power MOSFETs etc. depending upon the application.
- AC voltage controllers or AC regulators: They are employed to get a variable AC voltage of the same frequency from a single phase or three phase supply. Some such controllers are Auto transformers, Transformers with various taps and Converters using Power electronics devices.
- DC to DC converters: They are used to get variable DC voltage from a fixed DC voltage source using Power electronics devices. Smooth step less variable voltage can be obtained with such converters.
- Inverters: They are employed to get variable voltage /variable frequency from DC supply using PWM techniques. Inverters also use the same type of Power electronics devices like MOSFETs, IGBTs, and SCRs etc.
- Cyclo-converters: They convert fixed voltage fixed frequency AC supply into variable voltage variable frequency supply to control AC drives. They are also built using Power electronic devices and by using controllers at lower power level. They are single stage converter devices.

2.3.4 Control Unit:

Whenever semiconductor converters are used, the control unit will consist of firing circuits which employs linear and digital integrated circuits and microprocessor, micro controller, DSP when sophisticated control is required.

2.3.5 Sensing Unit: It performs two functions

1. Speed Sensing: It is required for implementation of closed loop control schemes. Speed is usually sensed by tachometer, digital tachometer, optical encoder etc.

2. Current Sensing: it employs two methods

- Use of current sensor (Hall Effect Sensor)
- Non-Inductive resistance shunt in conjunction with an isolation amplifier which has an arrangement for amplification and isolation between power and control circuit.

2.3.6 Source:

Very low power drives are generally fed from single phase source. Low and medium power motors are fed from 400 V supply .For higher rating motors may be rated at 3.3 KV, 6.6 KV, 11 KV. Some drives are powered from a battery. Battery voltage may have 24V, 48 V and 110 V DC.

2.3.7 Switching Circuits:

We need switching circuits to achieve the following operations,

- For changing its quadrant operation
- For operating motors in predetermined sequence.
- To provide interlocking to prevent malfunction.
- To disconnect motor when abnormal operation conditions occurs.

3.0 Stator Variable Voltage and Variable Frequency Control:

The synchronous speed is given by NS = 120 f /P. Thus by controlling the supplyfrequency smoothly, the synchronous speed can be controlled over a widespeed range. But form the basic transformer voltage equation we have theexpression for the air gap flux:

V = [4.44 K1 Φ Tphf] from which Φ= [1/ 4.44 K1 Tph] (V/f)

Where K1 = Stator winding constant , Tph1 = Stator turns /phase,V =Supply voltage and f = Supply frequency

From the above expression it can be seen that if the frequency is reduced theflux will increase which results in saturation of the stator and rotor magneticcores. This saturation in turn results in increase in magnetization current (noload current) which is undesirable. Hence it is required to maintain the air gapflux constant when supply frequency is changed. From the above expressionfor flux Φ we can see that this can be achieved by changing the Voltage alsocorrespondingly so as to maintain a constant V/f ratio. Hence with V/f controlmethod which ensures constant flux Φ, we can get smooth speed control.Such a constant V/f with both variable voltage and frequency can be obtainedusing a electronic converter and an inverter as shown in the **figure-1** below.

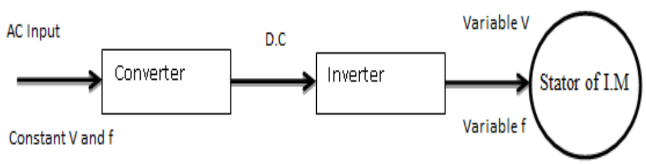


figure-1

The converter converts the normal input power supply into DC. The inverterthen converts the DC supply into a variable frequency supply as per the speedrequired but maintaining a constant V/f.

If f1 is the nominal frequency, thenthe **figure-2** below shows the Torque – slip characteristics with frequency f5< f4<f3< f2< f1

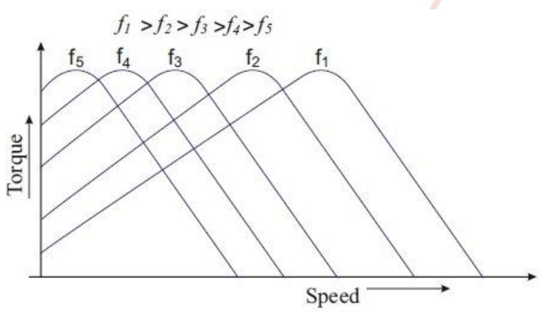


figure-2

3.1 Important Concepts.

- Synchronous speed of an induction motor is directly proportional to the supply frequency. Hence by changing the supply frequency the synchronous speed and hence the motor speed can be varied.
- The motor terminal voltage is proportional to the product of thefrequency and the flux neglecting the stator voltage drop as given by therelation: v(t) α ω.φ. Hence any reduction in the supply frequencywithout a corresponding reduction in the Stator voltage would cause an increase in the air gap flux and a corresponding increase in themagnetisation current which is not desirable.
- Hence to avoid excessive magnetisation currents and also to maintainthe torque constant, variable frequency control below the base speed isnormally carried out by reducing the stator voltage along with frequencyin such a manner that magnetic flux is maintained constant. This methodis called constant V/f control. But above the base speed, the statorvoltage is maintained constant because of the limit imposed by thestator insulation or by supply voltage limitations and hence thedeveloped torque would come down.

3.2 Dual Winding Synchronous Motor AC Drive:

In some of the power plants , dual windings synchronous motors are used in Induced Drafts (ID) Fans for which Variable Voltage and Variable Frequency Control System (VVVFD) is used.

Dual Winding Synchronous Motor is a motor with 2 stator windings on same stator with 30 magnetic degrees apart construction, and fed by electrical voltage upto 2.3 KV to 4.3 KV with variable frequency and 30 electrical degrees apart. The rotor is wound rotor supplied with controlled DC with brushless excitation system.Rotor is fed from a Diode wheel assembly. The Diode wheel is rectifying the A.C. from wound rotor of Exciter, which is inducing voltage by application of controlled voltage (AC) to its stator [exciter Stator].Refer **figure-3**

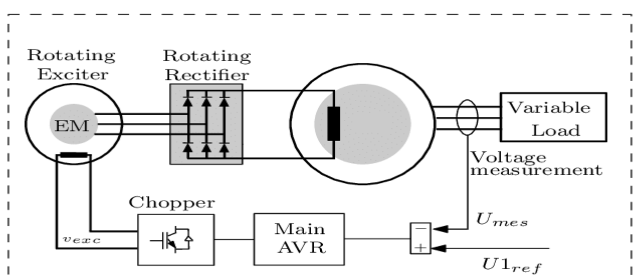


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figure-3

An example of Dual Winding Synchronous Motor Rating is as following.

Base armature current per channel: 616 Amp
Base Voltage: 2300 V
Base Speed/Frequency: 525 Rpm/43.75Hz
Base Exciter Current: 150Amp.

The drive has 2 stator windings 30^0 spatially and 30^0 electrically apart.

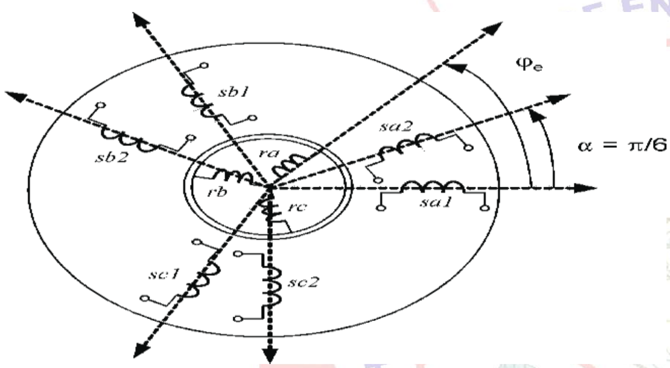
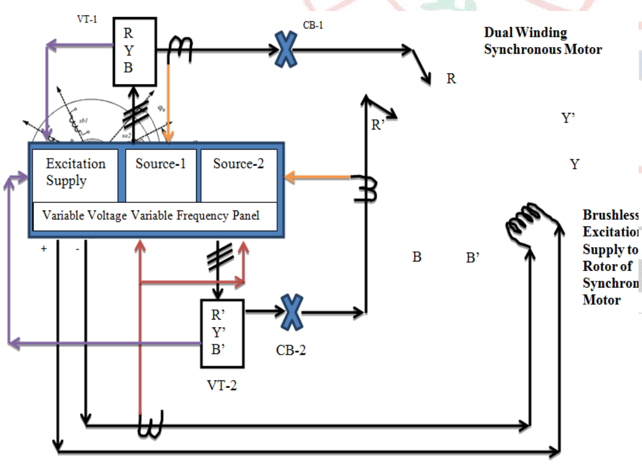


figure-4

The power supply diagram of a 3 Phase Dual Winding Synchronous Motor is shown below in **figure-5**



4.0 Problem:

Basic Problem in Dual Winding Synchronous Motor is direction of rotation during initial commissioning of motor with two diffeent power supplies.It was observed that when the said motor is operated by Source-1 of VFD Paneland the motor is rotating in opposite direction let say anticlockwise direction when run individually with source-1 supply.However when the motor is operated by Source-2 of VFD Panel runs in correct direction let say clockwise direction when run individually with Source-2 Supply.The above problem need to be rectified because in normal condition the motor has to be run in clockwise direction direction with both power supplies in on condition for both windings.

Note: Direction of any 3 Phase AC motor can be changed by reverersing any two terminals of input power supply.

So in normal practice ,by reversing/swaping any two stator terminals leads to change in the directon of rotating magnetic field and consequently the direction of motor changes.

However as the motor is dual stator wound synchronous motor and there are every chances that there may be resulting phase transposition while changing any 2 leads of stator winding with respect to other winding which must be always 30 deg electrical for smooth running of motor.

5.0 Analysis and Solution:

The following method was employed for ensuring correct phase connection for ID fan motor stator and found successful.

Method of reversing phase sequence connection for winding-1,

1. Run the motor with Source-2 in which direction of rotation is normal (Clockwise) with original connections.
2. If the direction of rotation with this Source-2 is clockwise and being excitation controller in provided with closed loop feedback system , then exciter must draw controlled low current with all possible combination of exciter connection.
3. Now with all precautions, mechanically close load breaker (CB1) of Source-1 , by doing so, the

3-Phase induction voltage from charged winding-2 from source-2 will be reflected in winding-1 upto VFD panel.The voltage feedbacks of Source-1 and Source-2 can be measured at VT1 (R,Y,B) and VT2(R', Y',B').

4. With the help of Dual trace Oscilloscope check the vector relation (spatial arrangement not amplitude) at VT2 (R', Y',B') of source-2 with VT1 (R,Y,B) of source-1 , it must be 30^0 lag or lead with each other, if not then change the stator leads (any two at a time) of the Source-1 with which motor is rotating in opposite direction, in a manner such that this spatial arrangement is maintained 30 Deg apart as shown in below **figure-6**.
5. Now stop the motor and allow it to coast down to standstill, change the stator terminals of source-1 (any two) in which the spatial arrangement is maintained 30 deg w.r.t other Soure-2.
6. Now run the motor individually with source-1 , now the motor should run in correct direction with source-1 with exciter current same as when the motor run individually with source-2.

However in case the motor is running opposite with both channels, following modification of procedure is to be adopted.

7. Change phase sequence of stator winding terminals (any two) for any source either-1 or 2 randomly.
8. Run motor uncoupled with the source where phase terminals were changed to make the direction of rotation clockwise and check the exciter current with various all combinations of exciter connections possible.The exciter current under normal condition must not exceed 20% of rated per phase current under normal running conditons.The connections for which motor is drawing minimum exciter currentmay be considered correct.
9. Now repeat procedure from **Serial No.3-6** for motor having only other source with opposite direction.

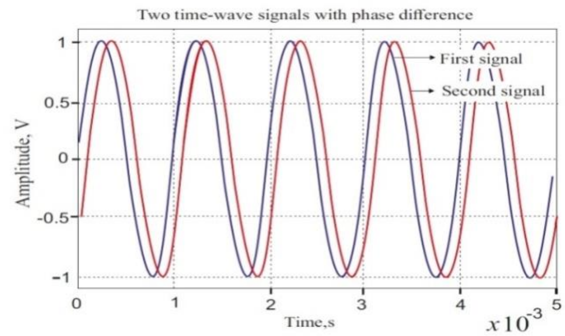


figure-6

3. CONCLUSION

The above procedure has been developed and employed for ensuring correct phase connection for AC Electric Drive (Synchronous Motor) having dual windings in the stator and may be utilised as a general procudure wherever dual winding syncrhronous motor is used.

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