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Research Paper

VVVF DRIVE-FEATURES, COMMISSIONING PROCEDURE AND CHALLENGES

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INTRODUCTION

A VVVF drive is acronym of variable voltage variable frequency drive. This is a solid state unit having capability to deliver power with variable voltage and variable frequency. It shall be possible to run motors at different speeds.

The speed of the motor shall be varied as per the process/functional requirement. The same can be achieved by using VVVf drive. Number of Drives are used in SPP, mainly to achieve micro speed in EOT crane and in other application like speed control of pumps, blowers, etc.

This paper deals with the basics of VVVf Drive, its advantages, the commissioning procedure and selected case studies which enumerates the challenges and the solution. Also apart from presenting normal Drive application, the extended application like

- Using a single Drive for two roller stand equipments,
- Utilizing communication capability of Drive for controlling and acquiring data without multi core cable, CT and transducers.

Since we are handling, large no drives of various capacities and various makes, we have gained significant experience in these drives and few case studies are described in this paper.

BASICS OF VVVF DRIVE

Why both voltage and frequency needs to be varied?

We know that, Speed N =120 x f/P

where

N is speed of the motor

f is frequency of the supply voltage

P is number of poles of the motor.

The speed is proportional to frequency. By changing the frequency, we can vary the speed. But flux Ø = v/f. If frequency alone is changed by keeping the voltage constant, flux Ø varies,Speed also varies along with flux. We

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know that Torque is proportional to product of flux (Ø) and armature current (Ia). Since flux is changing, the torque also changes. This is undesirable in maqny applications.

And also, If the frequency alone is reduced, the inductance of the motor coil will be very low. ($X_L = 2\pi fl$) and therefore the motor winding draws excessive current which may result to burning of the motor.

Hence we have to vary both voltage and frequency to maintain constant flux in turn constant torque.

Conversion of AC voltage to DC voltage is done by diodes.

Inversion from DC voltage to Ac voltage is done by Insulated Gate Bipolar Transistor (IGBT) in a simple VVVf Drive.

FEATURES AVAILABLE IN VVVF DRIVE

The following features are available in VVVF drives.

- Speed control with encoder
- Speed control without encoder
- Free blocks like Logic gates, timers, counters, etc., available for making the different types of logics.
- Communication capability
- Different operating stations for control, i.e., VVVF drive Panel, Terminal and through communication like Profibus, etc.

Advantages and Disadvantages of VVVF drive:

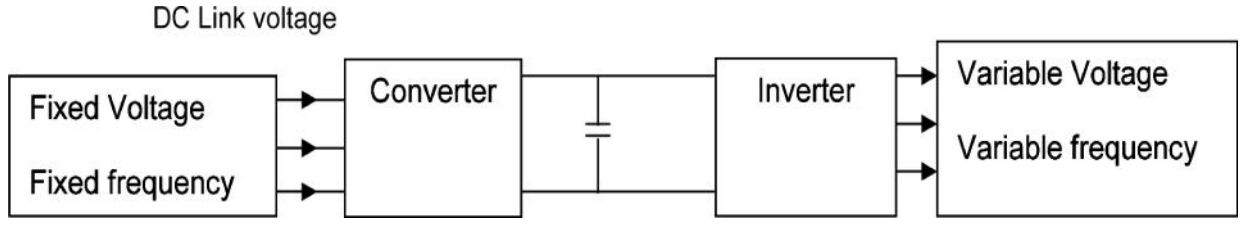
Advantages

- Variable speed at motor shaft
- Conservation of power (In case of pump loads)
- Quick reversal (contactor is not required).
- Reduced wear of brake liners due to application of brake at low speed using Drive.
- Smooth acceleration and deceleration using Ramp Up and Ramp down time to avoid sudden load on mechanical system and smooth handling of loads without Jerk.
- Due to absence of contactors, pitting of contact tips is avoided and maintenance is reduced.
- Good reliability and availability
- Reduction of inrush current
- Inbuilt protection like OC/SC

Disadvantages

- Initial cost
- Harmonics generation

Figure 1: Block Diagram of VVVf Drive



- Expertise is required for programming during commissioning and for rectifying faults.

VVVF DRIVES AT SPP, SDSC SHAR

Nearly 150 no's of various capacity of drives are being handled at Solid Propellant Plant for different application like

1. Handling equipment like crane (major portion)
2. Pumps
3. Blowers
4. A P grinding mill
5. Rollers stand for rocket motor hard ware rotation
6. Small capacity mixer used for sample processing
7. Vacuum driers

The Capacity of drives available at SPP is ranging from 0.75 k W to 132 kW of different makes.

SELECTION OF VVVF DRIVE

The major parameters to be specified/ considered for selection of drive is given below.

PROGRAMMING, LOGIC BUILDING AND COMMISSIONING OF VVVF DRIVES

- Power and control connections are to be established.
- Drive is to bepowered from normal power

Table 1

S. No.	Parameter to be Considered for Selection	VVVF Drive Selection Criteria
1.	Motor Capacity	Equivalent or one step upper side can be considered
2.	Type of application	• Crane
		• Pump
		• Blower
3.	No. of Motors to be operated	Single drive/multi drive
4.	Motor voltage	3Ø 415 V
		3Ø 220 V
5.	Input Voltage	1 phase/3 phase
6.	Control station of VVVF drive	Drive Panel
		Terminal
		Profibus
7.	No of Inputs and outputs required for operation	Number of DIs/Dos/ AIs/AOs
8.	Communication Capability	Profibus
		RS 485
9.	Line filters	This is to be considered for not allowing the harmonics to source
10.	load side chokes	To improve the sine wave
11.	Semiconductor fuses	Suitable rating to be considered for VVVF drive protection

- Factory reset is to bedone to VVVf drive.
- Quick commissioning is to be carried out as per the procedure which involves the following steps.
  - Motor data is to be entered as per name plate details
  - Frequency source is be provided
  - Minimum and maximum frequency is to be provided.

- On/off selection location to be mentioned, i.e., Drive Panel, Terminal, Profibus communication (SCADA)
- Ramp up/ramp down time is to be selected
- Types of control to be selected based on the application of the motor, i.e., Sensor Less Vector Control (SLVC)
- Closed loop control
- V/f control
- If closed loop control is selected, encoder is to be enabled.
- Motor data identification to be carried out, i.e., acquiring equivalent parameters values from the motor. This is achieved by giving power to Motor for few seconds and VVVF drive will acquire relevant data of the motor like equivalent resistance, inductance, capacitance, etc., and store in the memory.
- End of quick commissioning.

Assignment of Digital/Analog Inputs in the Programme: This is to be carried out correctly for proper operation of the total system. The physical inputs from push button station (DI) or potentiometer (AI) for on/off and frequency set point are connected to VVV drive. This is read by drive and accordingly it delivers the output to motor.

Assignment of Digital/Analog Outputs: For example, Building up of logic for executing a digital output for opening of brake is demonstrated here for logic building of EOT crane application. As an example, one typical DO assignment was explained below.

(Digital Output Assignment)

Mechanical Brake is one of the important devices in EOT crane operation. This Fail safe Mechanical brake ensures safe handling of loads without slip during EOT crane operation/ power failures.

In conventional crane the brake logic is simple. The brake supply is tapped from Motor supply and whenever the motor is energized brake is also energized and open. During Motor Off condition or during power failure, the brake deenergizes and due to spring tension (Fail safe) holds the brake drum.

However, when using VVVf drive, the brake supply cannot be tapped from motor for the simple reason that the motor gets variable voltage depending on the speed requirement but the brake needs constant voltage for its operation.

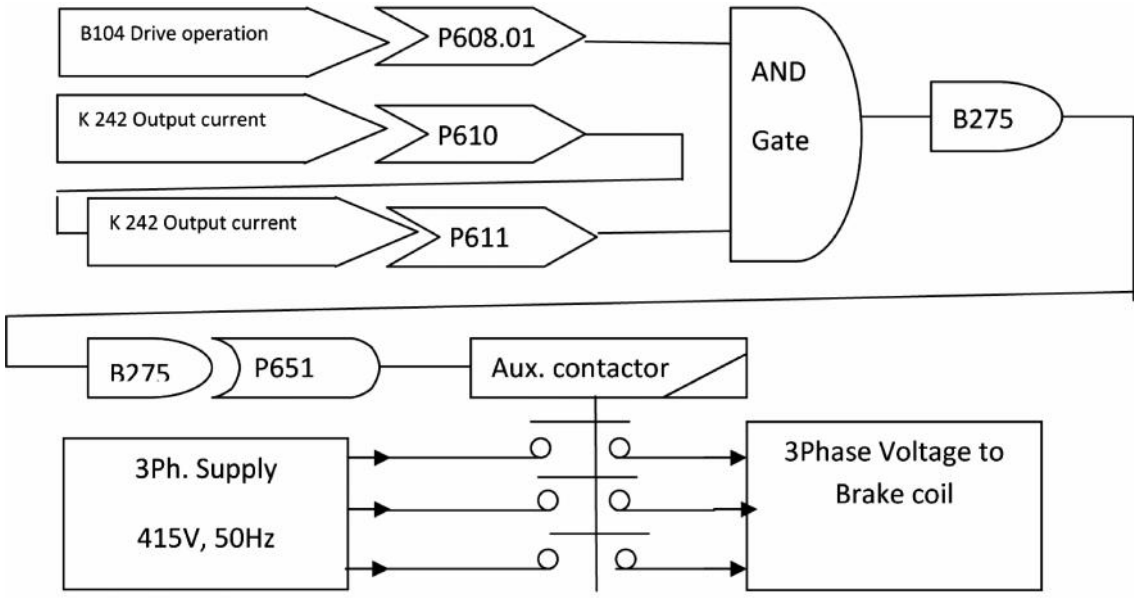
The brake supply is extended from mains (drive input) through a contractor. The contactor is switched on using Digital Output (DO) command of Drive. The brake logic is built on this particular DO.

When brake is released, then only motor will operate and when motor stops, break has to hold the shaft of the motor, otherwise shaft will rotate due to inertia and load will be moved. Hence brake logic has to be given importance in view of safety. Hence, the logic building for brake is very important.

The brake shall release only when motor develops sufficient torque and closes when motor reaches near zero speed or nearer to zero speed condition.

The brake logic is built as follows:

Figure 2: Logic Building for Brake Opening



After completion of the above steps the VVVf drive is ready for operation and shows status as "Drive ready for operation parameter".

After this, if "On" command +Frequency set point is given, the drive starts feeding the motor.

LESSONS LEARNT

Experience gained with VVVF drives:

Incorporation of Micro Speed for 3.2t EOT Crane with the Help of VVVf Drive in AP Drying Facility at SPP

The creep operation for 3.2t crane was incorporated in house with available spare VVVf drive of micro master of Siemens make. The drive was kept in FLP panel and all power connections were established. Programming of VVf drive was carried out as per the procedure. No load trials were carried out successfully.

When Load testing was planned and rated load was lifted, VVVf drive was working normal, But when down operation was performed; drive tripped on "DC link voltage high". This had happened due to less value of dynamic braking resistor connected to the DBU.

Remedial Action: The DBR of correct rating was provided by trial and error method by making series and parallel combination dynamic braking resistor, it could able to perform the Down motion without any trip. The approximate resistance value used is 2.5 Ω.

Checks are to be Done During Taking Over of the VVVf Drive Based Cranes / Systems

During handing over of the crane at vertical mixer-3, the functioning of encoder was erratic and was not working. The crane erection engineer has disabled the encoder and shown the operations of all motions.

We have checked the encoder parameters and found that the encoder was disabled and shown him. Then he replaced with new one. Encoder enabling parameters in master drive of Siemens make are as follows.

Table 2

Parameter Number	Setting of Indices	Description of the Setting
P65	5	Setting mode
P100	4	Speed control mode
P130	11	Pulse encoder
P151	1020	No. of pulses
P60	7	User mode

Table 3: Encoder Disabling Parameter

Parameter Number	Setting of Indices	Description of the Setting
P65	5	Setting mode
P100	1	V/f mode
P130	10	Without encoder
P60	7	User mode

By making the encoder disable, the erection engineer has run the crane. Since encoder is physically connected to the motor shaft and rotates along with the motor, we assume that encoder is in line. If we are aware of the encoder enabling parameters, this type of problems can be eliminated.

Assignment of Brake Logic Parameter not Proper During Commissioning

In one of EOT cranes, brake logic programme was not properly assigned by the commissioning engineer of VVVf drive. Even though the DO was not assigned properly, due to other hardware interconnections the logic was functioning normal. During T&E, when the input power to drive was interrupted and restored and the hoist up command was executed, drive got tripped under parameter No. F008 which is “DC link voltage low” but VVVf drive has given command for brake to open.

This type of problems can be eliminated if proper care is taken during commissioning. This problem was rectified by providing the proper parameter in the drive logic programme.

Compatibility Checks were Carried Out for Various Types of VVVf Drives to Suit with Siemens make Drives

We have different capacities and different makes of VVVf drives like Siemens, ABB. Yaskawa, and Allen Bradley, etc.

Out of the above brands, 90% of VVVf drives are of Siemens make and others are 10%. We have procured spare drives of Siemens make. To eliminate the investment of capital on maintaining spare drives for 10% of other brands, we have carried out compatibility checks with Siemens drives.

During failure of any of the above drives, we can use Siemens make drives as spare and put the system in normal operation.

This we could achieve by making compatibility checks with Siemens VVVf drives.

- The steps to achieve the same are
- Power rating is to be checked.
- Number of Control inputs (DI) and control out puts (DO) are to be checked.

- Number of AI (from potentiometer) and AO (for meters) to be checked.
- Weather the required logics can be built with available Drive.

Using the above steps, the programme was generated with Siemens make drives, compatibility of I/Os have been checked and procedure has been generated and kept ready.

The advantages of above exercise are as follows.

- Elimination of capital cost on the investment of spare drives for all models/makes.
- Time required for replacement of drive will be minimized since we have laid down the proper procedure.
- Confidence level of maintenance personnel will be improved.

The following compatibility checks of various drives have been carried at different facilities of SAPP.

Two Rollers Stand Needs to be Run with One VVVf Drive at HIL Facility

S200 roller stand is having a VVVf drive of capacity 9.3 kW at HIL Facility, SPP. Recently S139 roller stand has been added to the facility to make rubber lining to S139 segments. Both motors are of 9.3 kW capacity but having different speeds. But this Roller stand was not having Drive to have variable speed.

As variable speed was the process requirement to achieve better results, it is planned to utilize the existing drive without resorting to procurement.

The available Drive is having capability to store the logics in two different indices. Both indices can be operated as per the selection. Using this feature.

For each motor we have generated a programme according to name plate details of the motor, process requirement and stored the programme in different indices.

By using a selection bit, the respective programme will be loaded to VVVf drive as per selection. This is achieved with the help of digital inputs combination.

Data Acquisition and Control Through Communication Capability of VVVf Drive

The data related to VVVf drive can be retrieved by utilizing communication provision between VVVf drive and PLC, SCADA. The control of VVVf drive can also be done by this provision. With this, parameters like current, voltage, frequency, DC link voltage, etc., of VVVf drive can be monitored and logged without running control cable and without CT, transducer and

Table 4: For Example

S. No.	Facility Name	Equipment Name	Motor Capacity	VVVF Drive make and Capacity	Compatibility Check with make of
1.	AP Grinding	Feed motor	0.75 kW	ABB 1.1 kW	Siemens2.2 kW
2.	HIL	Roller stand	9.3 kw	ABB 9 kW	Siemens 18.5 kW
3.	ISPF	100 L mixer	9.3 kW	Yaskawa-11 kW	Siemens 18.5 kW
4.	ISPF	4 L mixer	0.75 KW	Allen Bradley	Siemens1.1 kW

control cable. This is useful in analyzing the motor/VVVf drive performance.

Maintenance of Spare Drives- Proper Care Needs to be Taken

If we have spare VVVf drive, we need to put the spare drives in operation periodically, i.e., the spare drive has to be kept in operation and the removed VVVf drive can be kept as spare. This will ensure the health of the drive. If this practice is not followed, and the drive is stored for long time (more than a year), the drive needs FORMING which is applying the AC voltage gradually from zero to till it reaches rated voltage.

CONCLUSION

VVVf drives are having many advantages. But proper care needs to be taken during commissioning as well as operation and maintenance. Improper parameterization and mishandling causes malfunctioning of the VVVf drive and in turn damage/accident may occur to the equipment, personnel, properties, etc. Proper care needs to be taken while building the logics for brakes, etc., which shall support for safe operation since we are handling hazardous/explosive nature of materials.

VVVf drives of various capacities have been commissioned in all SPP facilities, successfully. In the last 5 years during processing/production of solid rocket motor in SPP, the drives have been effectively used for safe handling of propellant materials, segments, etc. Also capability of VVVf drive have been optimally utilized during trouble shooting analysis of its systems.

Electrical team of SPP is fully conversant with and tackle any problem associated with VVVf drives in SPP.