AC Vane Relay (VT1) Applications

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Overview

Vane Relays are used in AC track circuits. A vane of an aluminum alloy is secured to a horizontal shaft, with a trunnion at each end, which is supported by bearings. They accurately position the vane in the air-gap between the two magnetic field structures with ample working clearance. The local and control windings are fastened to the base of the relay, thus providing conduction of heat from the coils and laminations to the outside air. Both the vane and magnetic structure are compact, yet are designed for correct distribution of mass and magnetic flux. Pushers of insulated material transmit the movement of the vane shaft to the contacts. These contacts are similar to the ones used in DC relays, being flat springs molded in a phenolic block.

The vane is supported so that it is free to rotate. If a permanent magnet is rotated about the disc shaft in such a way that the magnetic lines of force cut through and across the disc, the disc will start to rotate in the same direction as the permanent magnet, and at a slightly slower speed. When the permanent magnet is rotated, the magnetic lines of force cut the disc and produce a voltage between two points on the disc. A current, commonly known as an “eddy” current, flows between these points and back to its origin by the shortest path. These eddy currents produce small magnetic forces that react with the magnetic force of the permanent magnet, producing rotation.

In the Vane Relay, two electromagnets are constantly energized while the relay is picked up, but the magnetism produced by one of the electro-magnets lags in time with respect to the other. The reaction on the Vane Relay of the two independent magnetisms, which are out of phase, produces rotation, the same as that produced by the moving permanent magnet. The alternating current produces a lateral movement of flux in the air gap.

For the relay to produce maximum torque with the minimum power input, the local and control current must be out of step by a quarter of a cycle or 90 degrees. In capacitive fed vane relays, this 90 degree phase shift in the current waveform is imparted by a band-pass filter; constructed by the wiring of a capacitor across part of the control coil winding. Track relays, under adverse track conditions, may require a phase-shifting device inserted in the local phase to approximate the ideal current relationship.

Suitability

Please Note

- The VT1 variant of VTi21 firmware has been specifically tailored for use with VT1 relays.
- It is not designed for use with other types of AC vane relay, such as CE391 or G4.
- The VT21 can be readily adapted to monitor alternate forms of AC relay. If you have a requirement to monitor relays other than VT1's, please contact mpec.

Installation

To monitor the performance of a VT1 relay, the currents flowing through both the local coil and control coil must be monitored.

- The feed to the local coil must pass through the current transducer connected to the "LOC" input on the VT21.
- The feed to the track coil must pass through the current transducer connected to the "CTR" input of the VT21.

The CTR input is labeled as TRK (for track coil) on units with serial number 0001 and 0002 - This was due to a confusion in nomenclature during development - it will be referred to as CTR (for control coil) on all future units
Please observe the direction of current flow through the transducers. If one of the coil feed wires is fed through its transducer in the incorrect direction, this will result in a negative torque measurement where a positive measurement is expected.

Best results will be obtained if the feed to the track coil current is a true reading of the current through the coil. Ensure all conductors carrying coil current pass through the CT. This may often be two conductors for both the control coil and the local coil.

The CT must around all conductors that carry current to or from a Coil of the VT1 relay. The "vector sum" of the currents flowing in these wires will be equal to that flowing through the VT1 relay. Examples of these scenarios are shown below:
These example show the control coil, however similar wiring arrangements are often found at the local coil also.

VTI21 Outputs

The VTI21 sensor can output the following quantities when monitoring VT1 relays.
Vane Torque | -25 to +25 mN.m
--- | ---
Local Current | 0 to 500 mA
Track Current | 0 to 1000 mA
ABS Phase Difference* | 0 to 180 Degrees
Chatter | 0 to 100% Ratio of Chatter to Torque

The VT121 cannot tell if phase difference is lead or lag.

**How does the VT121 Work?**

The VT1 relay is designed to deliver maximum torque to the vane when the following electrical conditions are true.

- Voltage & current waveforms in the control and local coils are pure sinusiods at 50 Hz.
- The current flowing through both control and local coils are of sufficient magnitude.
- The voltage waveform in the control winding *lags* voltage waveform in the local winding by 90 degrees.
- The current waveform in the control winding is *in phase* with the current waveform in the local winding.

If any of these conditions are non-ideal, the VT1 relay will not achieve optimal output torque, although the relay will remain operationally functional with tolerable deviations in all of the above parameters.

The VT121 sensor is designed to continuously monitor these parameters, with a view to provide forewarning of failure, and diagnosis of fault conditions.

The VT121 software implements a mathematical simulation of the behaviour of the VT1 relay coils and vane assembly. It does this by mimicking the action of the resonant circuit formed by the winding inductance and tuning capacitor, and modelling the behaviour of the rotating magnetic field that cuts across the vane.

A summary of the computed output values and their interpretation is described below:

A typical local coil current and control coil current in the "track clear" state are shown below:

The harmonics present in the signal come from non-perfect voltage wave forms, usually generated by magnetic losses in step down or isolating transformers and track impedance bonds.

The magnitude of these waveforms will have a direct linear bearing on the amount of torque produced at the vane.

The VT121 implements a true RMS filter on these waveforms, and makes the RMS current of control and local coil available via the RS485 interface.

The value is computed every 1mS, with a low pas filter set to provide true RMS waveforms below 35Hz.
Post filtering, the VTI21 computes the phase angle between the control coil and local coil waveforms. This gives a real-time indication of the phase relationship between control and local coil current and voltage, with maximal torque generated at the vane when these two voltage signals are approximately 90 degrees apart. Note that the reported phase angle relates to the voltage waveforms, not the current waveforms.

The algorithm updates the phase angle every 20mS to avoid jitter.

When one of the coil currents falls near to zero, it becomes impossible to calculate the phase angle between waveforms accurately. When either coil current drops below 100mA RMS. The algorithm stops computation of phase angle and holds the last known good reading at the output until it is possible to reliably compute the phase angle once more.
After the control coil current has passed through the resonant filter the two waveform now appear as shown below.

The control current is heavily filtered by the resonant circuit formed by the tuning capacitor and the inductance of the track coil. The resonant circuit also imparts a 90 degree phase shift on the control current waveform at 50Hz. It is these wave forms that act to create a rotating magnetic field that induces movement in the vane element.

The true instantaneous torque experienced by the vane for these two waveforms is shown below.

The cyclic nature of the graph is due to the residual harmonics present in the driving waveforms. Two pure sine waves would produce a true "flat" torque waveform.

In the real world, the signals are never purely sinusoidal, and as such the torque waveform is cyclic, this is why VT1 relays can often be heard to "chatter" in operation.

Clearly outputting this waveform in real time would cause a vast amount of data to be produced that would be impractical for continual data-logging purposes.

To solve this, the torque waveform is filtered with an averaging filter to eliminate this ripple. The mean torque is therefore presented on the 4-20mA output and the RS485 interface.

A significant amount of "chatter" on the true torque waveform is indicative of a poor quality waveform being present on the relay coils. This can be caused by poor transformers and track bonding. It causes excess wear to the relay, and in severe cases can cause the relay to fail right-side.

The VT121 takes a measure of this "chatter" by averaging the the distance between the peaks and troughs in the instantaneous torque waveform over a 20mS period. The ratio of the amplitude of these peaks and troughs relative the mean torque is output on the RS485 Interface.

A reading of 0% means that the torque waveform is perfectly flat. A reading of 100% means that the chatter is of the same magnitude as the mean torque.

Immunity to DC

The VT1 relay is inherently immune to DC. The physics employed by the relay mean that for a DC signal to impart torque upon the relay vane would break the fundamental laws of nature.

The construction of the coil winding is such that the impedance to DC is incredibly low. It would take a significant DC voltage to be presented across the track coil for significant DC current to flow.

It does however remain credible that a significant DC current could cause severe damage to a VT1 relay, resulting in right-side failure.

Any incoming DC signal will also likely have AC superimposed upon it, and in practice, back to back clipping diodes placed across the track coil mean that the presence of DC is detected by the VT121 sensor as a clipped waveform. This will manifest as a lower torque reading and a higher jitter reading from the sensor.

Should the diodes fail, the iron core of the control coil can not support much additional magnetic flux above that of the expected AC track waveform; the control coil will quickly reach saturation when DC is superimposed upon an AC waveform. This once again results in clipping, and hence a lower torque reading and a higher chatter reading.
This means that although the current sensors employed by the VTi21 can not detect DC waveforms, the effects of DC upon a VT1 relay are readily detectable.