Tissue Machine Disturbance Analysis

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***Abstract* – Tissue Machine uptime is critical in today's business climate. A few hours of unscheduled downtime can cause disruptions in product shipment affecting overall profitability. This paper illustrates a procedure coined "Disturbance Analysis." The steps involve analyzing motor speed and torque fluctuations to determine whether a Tissue Machine instability problem is mechanical or electrical in nature.**

I. Introduction

A common complaint of Tissue Machine production personnel is that the speed of a roll is oscillating or swinging. The maintenance and production personnel need a technique to identify whether the oscillation is due to electrical control, mechanical drive train or process loading.

A transient or regular disturbance in the operation of a tissue machine will produce speed and torque disturbance signatures. "Disturbance Analysis" is the technique for analyzing the signature patterns of speed and torque.

II. Electrical – Mechanical Interaction

Disturbance Analysis assumes basic understanding of Electrical – Mechanical interaction of a Tissue Machine. Figure 1 illustrates a basic diagram of the Electro-Mechanical control of modern Tissue Machines.

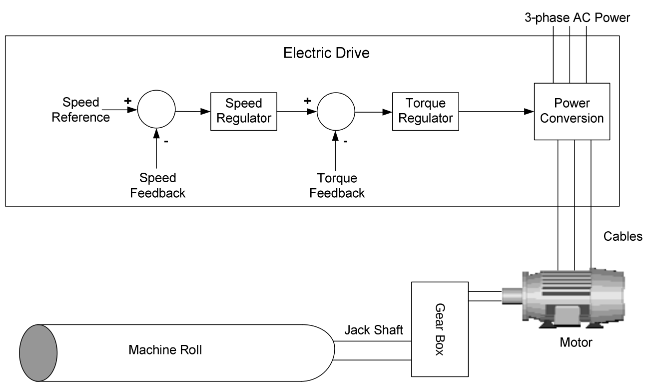

Fig. 1 – Electro-Mechanical Interaction

The speed reference to the electric drives is applied from a master controller. The speed reference is summed with the speed feedback from the encoder/tachometer. The error between the reference and feedback is applied to the speed regulator. The speed regulator output is presented to the torque regulator as a torque reference. The torque reference is summed with the torque feedback and the torque error becomes the input to the torque regulator. The output of the torque regulator is applied to the power conversion module and the output of the electric drive is adjusted accordingly.

The motor converts electric power to mechanical torque. Typically, a gear box connects the electric motor and the machine roll. The gear box reduces the motor speed to the appropriate speed necessary for the machine roll. The jack shaft, including connector joints, is the mechanical connection between the gear box and machine roll.[1] As illustrated in Figure 1, the Electro – Mechanical system is quite complex with multiple points of malfunction.

III. Data Collection

Data must be collected to interpret the speed and torque disturbance signatures. It is critical that the data be collected by one signal device. If two devices are employed for data collection, it will be extremely difficult to consolidate the data onto a graph with an accurate time reference. For analog drives, a chart recorder must be installed at the appropriate terminals on the drive. Either digital or analog chart recorders will collect the required data. Digital Chart recorders are preferred due to the large storage capabilities of the units.

For digital drives, a high speed data collection system is required to gather and store the data. The data must be collected at a minimum of 100 ms to accurately determine the frequency of the speed or torque oscillation. Data collection faster than 100 ms is preferred. If the data is not collected at a 100 ms rate or faster, the data might be misinterpreted. Figure 2 illustrates such a misinterpretation. With a sample rate of twice per second the data would be presented as signal 1. Signal 1 has a period of 2 seconds. Signal 2 is the actual signal which has a period of 200 msec. To avoid misinterpretation of data, the sample rate must be 100 ms or faster.

For analog drives, digital chart recorders provide better overall performance. The main advantages of digital chart recorders are they do not require paper/ink, the data acquisition rate is adjustable, data storage is only limited by hard drive space, data can be analyzed in real time and data can be up loaded to a laptop computer for further analysis. The chart recorder must provide signal isolation and noise filtering. Voltage suppression may be required. A multiple channel recorder is required to simultaneously exhibit the speed and torque disturbance signature patterns on the same chart for comparison.

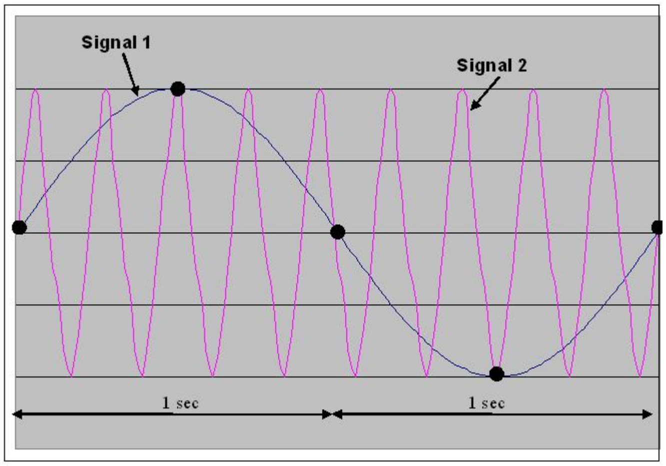

Fig. 2 – Data Misinterpretation

IV. Disturbance Patterns

The first step in the Disturbance Analysis process is to acquire a graph of speed and torque. From the graph a pattern signature can be determined. The pattern signature can be categorized into two groups -- random or cyclic. As explained, it is critical that the speed and torque data be collected by one device. One source data collection will ensure data has the correct time reference.

Pattern Categories

A random pattern is illustrated by an impulse fluctuation and a varying time between the impulse fluctuations. See Fig. 3

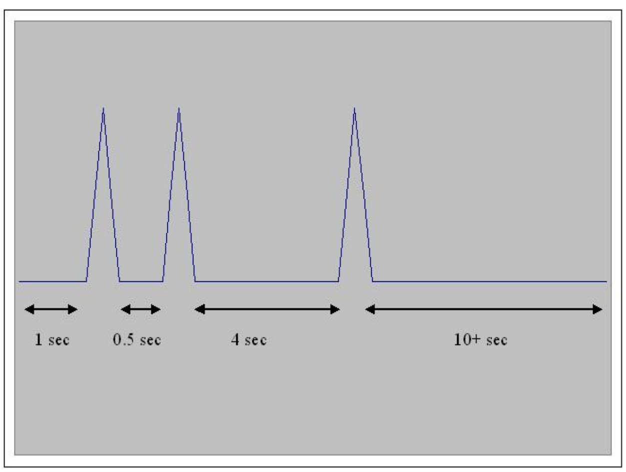

Fig. 3 – Random Pattern

A cyclic pattern is illustrated by a set period between the amplitude peaks of the fluctuation. The frequency of the fluctuation can be calculated to determine if the cyclic signature matches the speed of the roll or motor. See Fig 4.

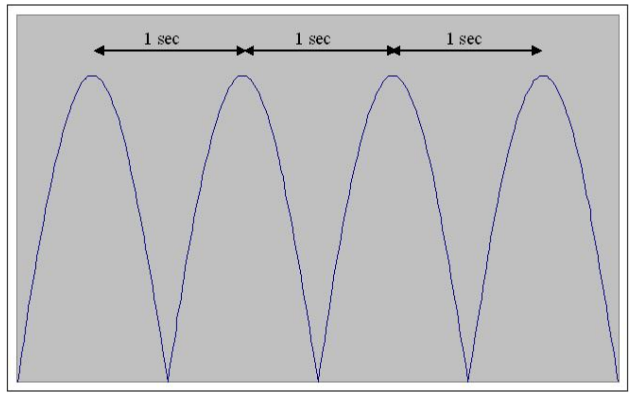

Fig. 4 – Cyclic Pattern

V. Analyzing Patterns

The second step of the Disturbance Analysis process is to determine if the speed and torque fluctuations are the same or opposite during the disturbance. Each disturbance can be categorized as follows – Random and Same, Random and Opposite, Cyclic and Same or Cyclic and Opposite. The analysis will reveal if the origin of the drive section malfunction is in the electrical control, in the drive train or in the process load.

Random and Same

A random pattern disturbance of speed and torque changing in the same direction indicate a malfunction of the electrical drive system. The random pattern results because most electrical malfunctions occur with no specific time relationship. The same direction pattern results due to a speed increase causing a corresponding torque increase to attain the increased speed reference. A speed decrease necessitates a torque decrease. Consequently, an electrical control malfunction exhibits a same direction pattern as shown in Fig. 5.

A typical malfunction in an analog drive system can result from a drifting regulator reference voltage, an intermittent connection in the section draw pot, a momentary change in the drive sequence command, a loose wiring connection to a card or power component, a recurring ground fault or a gain change in the regulator circuit.

In digital drive systems, the common causes include microprocessor controller card fault, a loose wiring connection between circuit cards or power component and communication problems across a LAN (Local Area Network) between the drive and master controller.

Random and Opposite

A random pattern disturbance of speed and torque changing in the opposite direction indicates a malfunction of the encoder/tachometer circuit or process load. A second speed sensor is required to determine if the disturbance is a malfunction of the encoder/tachometer circuit or process load. The second recording will be compared to the first recording to discern a change in the speed and torque direction.

A change in the speed and torque direction, such that the speed and torque in the second recording change in the same direction indicates a malfunction of the encoder/tachometer circuit. The reason is that the faulty tach circuit incorrectly determines speed feedback thus causing a torque action in the opposite direction. The second speed sensor will determine if the speed changes in the direction of the torque.

No change in the second recoding such that speed and torque change in opposite directions indicates a malfunction originating in the process load applied to the section. The process load impedes the speed regulator's ability to maintain reference speed. Torque is applied in the opposite direction to maintain the reference speed.

Random and Opposite (Tachometer circuit)

Tachometer circuit failure must be detected with a second speed sensor. This pattern results because of a decrease in the tachometer output feedback causing a corresponding torque increase to attain the increase in speed necessary to produce the proper speed feedback. An increase in the tachometer output causes a torque decrease. A tachometer malfunction exhibits an opposite direction pattern as shown in Figure 6 with the recording. A recording with the new speed sensor will produce a signature pattern consistent with Fig. 5.

Typical malfunctions in the tachometer feedback circuit include an intermittent wiring connection or ground fault, increased electrical noise level in the tachometer feedback cabling, or a problem with a circuit card that converts tach pulses to a motor speed feedback.

Random and Opposite (Process Load)

Process Load malfunction must be detected with a second speed sensor. This pattern results because a torque increase caused by a process load causes a corresponding speed decrease until the motor attains the required power to maintain the speed with the increased torque. A torque decrease causes a speed increase. Consequently, a process load malfunction exhibits an opposite direction pattern as shown in Fig. 6. The 2nd recording with a different speed sensor will also exhibit a signature pattern similar to Fig 6.

Typical malfunctions in the process load result from changes in nip loading pressures, varying vacuum in the wetend section, doctor oscillator blades or changing dryer condensate levels.

Cyclic and Opposite

A cyclic pattern disturbance of speed and torque changing in an opposite direction indicates a malfunction in the section drive train. A malfunction in the various rotating elements within the drive train produces a cyclic pattern with a time period consistent with or a multiple of, the rotating element speed. Upon further analysis, the time period of the disturbance can identify the malfunctioning drive train element. The opposite direction pattern results because a load increase within the drive train necessitates a corresponding speed decrease until the motor attains the required power to maintain the speed with the increased torque. A torque decrease necessitates a speed increase. Consequently, a drive train malfunction exhibits an opposite direction pattern as shown in Fig. 7.

Typical malfunctions in the drive train can result from a defective gear or a defective machine roll. Malfunctions resulting from defective couplings, universal joints, or bearings and misaligned couplings can exhibit cyclic patterns with time periods that are multiples of the rotational speed.

Cyclic and Same

A cyclic pattern disturbance of speed and torque changing in the same direction indicates a malfunction in the electrical control system. The speed regulator output is the input to the torque regulator. So, an increase from the speed regulator to the torque regulator will cause both speed and torque to increase. The time period of the cyclic pattern will aid in determining the cause of the malfunction. See Fig. 8.

Typical malfunctions in the electrical control include software programming errors causing a varying speed command, electrical noise in speed command wiring or a faulty microprocessor controller card.

VI. Examples

Reviewing examples of production disturbances at various pulp & paper mills can be beneficial to maintenance and production personnel during troubleshooting situations.

Electrical Control Problems

Example 1. A first press speed was oscillating in speed. The chart recorder exhibited random and same direction patterns that indicated an electrical control problem. When the operator station was opened to replace the section draw pot, evidence of moisture was observed where water had been dripping on the terminal board at the draw pot wiring terminations. The intermittent water droplets created a low resistance ground fault in the speed reference circuit. Drying and sealing the operator's station stopped the speed oscillations.

Example 2. The reel section would speed up by 5 m/min breaking the sheet and return to operating speed within 5 sec. The problem occurred every 5 to 10 days. A trend was setup to monitor the internal speed command in the drive. The trend indicated the speed command from the master controller changed 5 m/min. The problem was determined to be a software programming error which would automatically inject an additional speed reference based on Reel Drum torque.

Example 3. A dryer section was decreasing randomly in speed. The recording indicated the speed and torque signals were opposite and random. The speed would decrease while the torque would increase. The printed circuit card where tach pulses are converted to an analog speed was replaced. The problem continued and a second tachometer pickup was monitored on a trend. When the event occurred, the speed feedback on the 2nd tachometer pickup increased while the torque increased. A faulty tach pickup was causing the problem. The alternate speed feedback sensor indicated an electrical control problem because the speed and torque were same and random.

Example 4. A press section would oscillate in speed by 2 m/min every 30 seconds. A trend indicated that speed and torque were cyclic and same. The cause of the problem was determined to be internal drive software. After a lightening strike, the electrical staff replaced a faulty main control card and loaded incorrect drive parameters into the drive. The incorrect parameters included a speed reference oscillator that was employed during tune-up of the drive. The electrical staff did not load the latest software for the press section. The correct parameters were downloaded and the problem disappeared. See Fig. 8.

Process Load Problems

Example 1. A Fourdriner section was oscillating in speed. The chart recorder exhibited random and opposite direction patterns that evidenced a process load problem. A check of the Fourdriner vacuum system revealed continual random vacuum variations at each suction box that ranged between five and twenty mm of mercury. When the vacuum system problems were resolved, the speed oscillation disappeared.

Example 2. The problem was sheet consistency variations on the wire and the Fourdriner speed oscillations. A chart recorder on the Fan Pump drive exhibited random and opposite direction patterns that evidenced a process load problem. A second Fan Pump recording from an alternate speed signal exhibited no change in pattern. A check of the Fan Pump stock injection system revealed a “burping” consistency regulator. When the regulator problem was resolved, the sheet consistency variations ceased and the Fourdriner speed oscillation disappeared.

Example 3. A second press was oscillating in speed. The recording exhibited random and opposite patterns that indicated a process load problem. A second recording from an alternate signal exhibited no change in pattern. An examination of the press loading air system revealed a check valve leaking into the backup plant air supply. Large random flow disruptions of plant air caused a change in nip pressure on the press. The swinging disappeared with the check valve replacement.

Drive Train Problems

Example 1. The problem was a Fourdriner speed oscillation. The recording exhibited cyclic and opposite direction patterns that evidenced a drive train problem. The time period between recurrent speed disturbance signatures was converted to revolutions per minute and matched to the rotational speed of the Flo-Vac belt. Based on the belt length and Fourdriner sheet speed, a fluctuation occurred with each revolution of the belt seam. The swinging disappeared when the belt was replaced.

Example 2. The problem was a third press speed oscillation. The chart recorder exhibited cyclic and opposite direction, a pattern that indicated a drive train problem. The time period between the recurrent speed disturbance signatures was converted to revolutions per minute and matched to the rotational speed of the machine top press roll as determined by the roll diameter and the paper machine operating sheet speed. The oscillation disappeared when the press top roll was replaced.

VII. Summary

Disturbance Analysis can be summarized in flow chart of Figure 9.

VIII. Conclusion

Disturbance Analysis is a process for both production and maintenance personnel to determine if Tissue Machine instability problems are caused by electrical or mechanical problems. The Disturbance Analysis process quantifies if a disturbance is random or cyclic in frequency of occurrence. Then speed and torque feedbacks are monitored to determine if the feedbacks change in the same or opposite directions. Once the disturbance is categorized as random or cyclic and speed and torque feedbacks are categorized as same or opposite, a determination can be made if the problem is in Electrical Control, Process Load, Drive Train or a Tachometer Circuit.

IX. Acknowledgements

The author acknowledges Boyce Tharpe for his original technical paper outlining Disturbance Analysis. Boyce Tharpe was a Senior Drive Systems Engineer with General Electric. He was a principle teacher of Electrical Drive Systems concepts and a lead troubleshooter.

X. References

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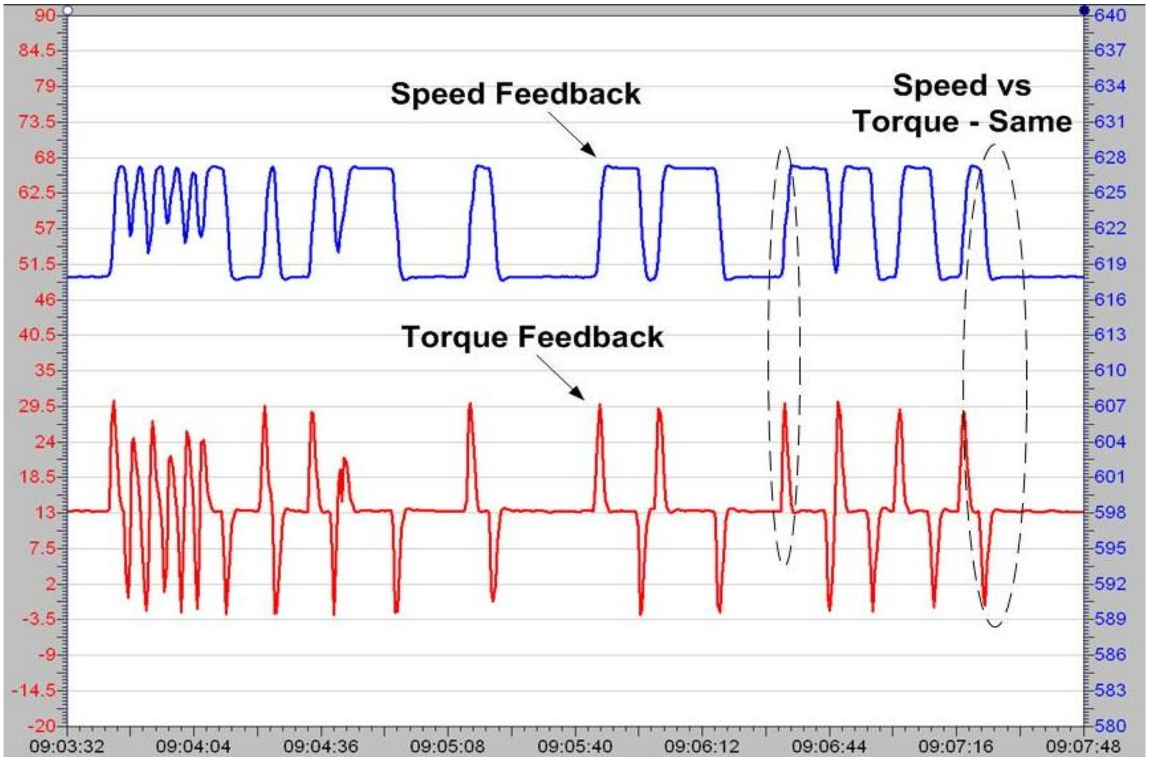

Fig. 5 – Random & Same

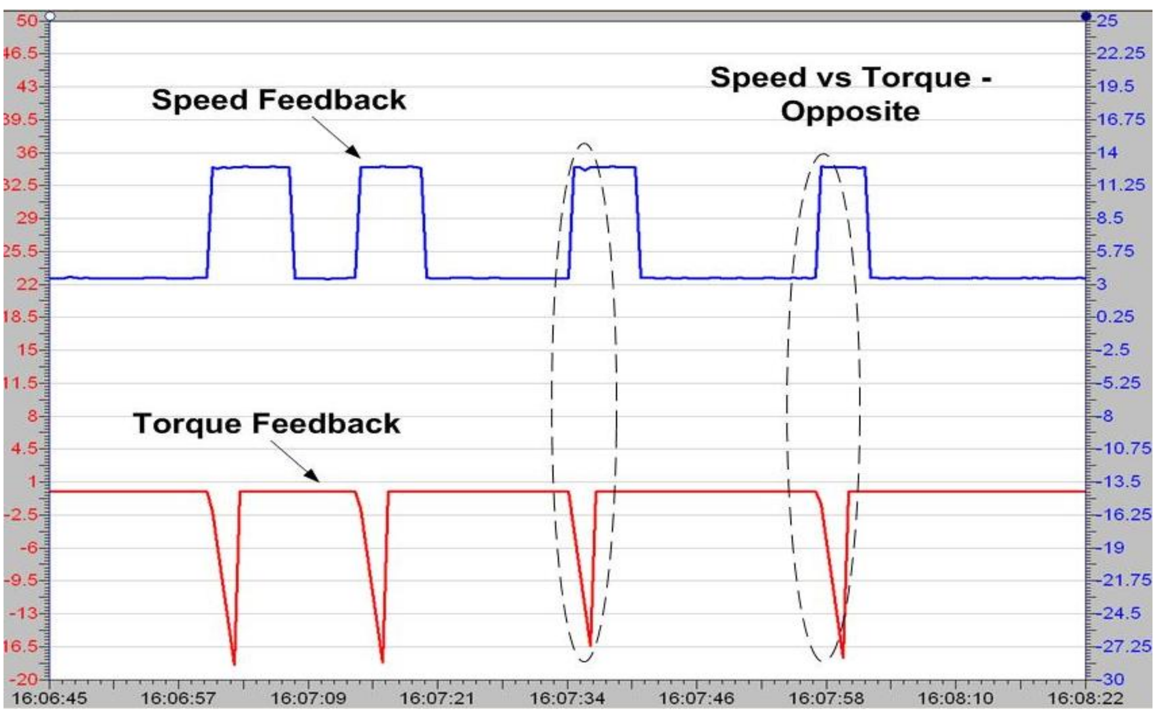

Fig. 6 – Random & Opposite

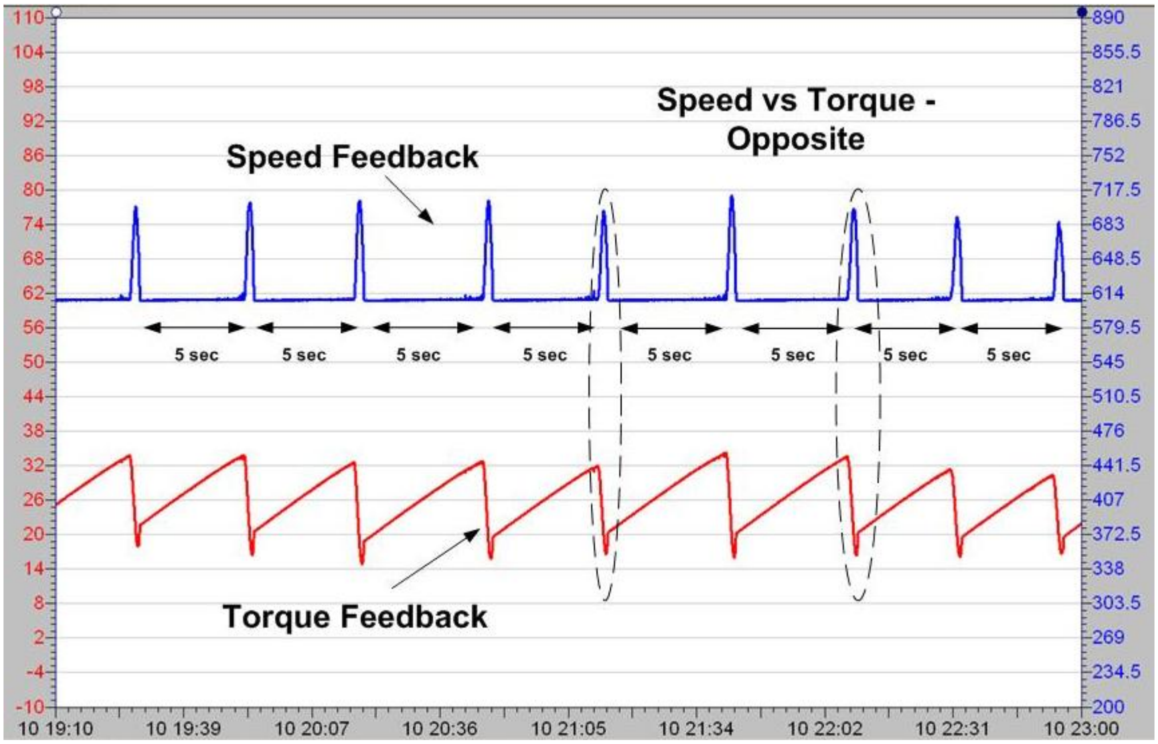

Fig. 7 – Cyclic & Opposite

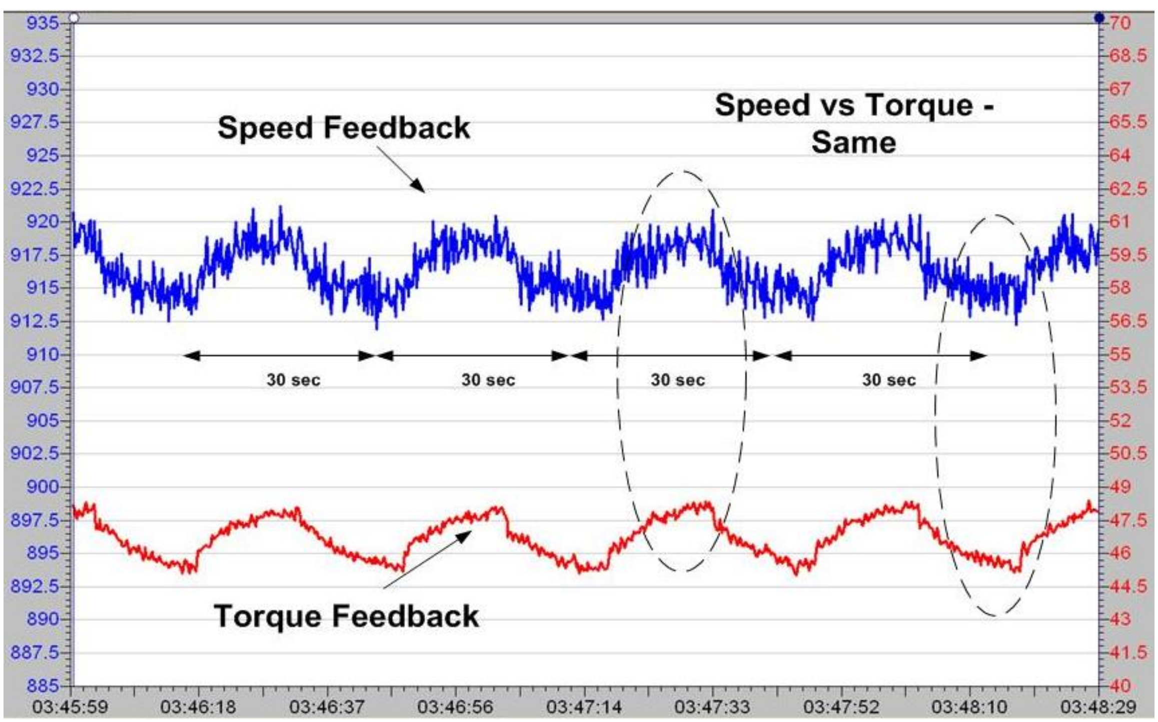

Fig. 8 – Cyclic & Same

Disturbance Analysis

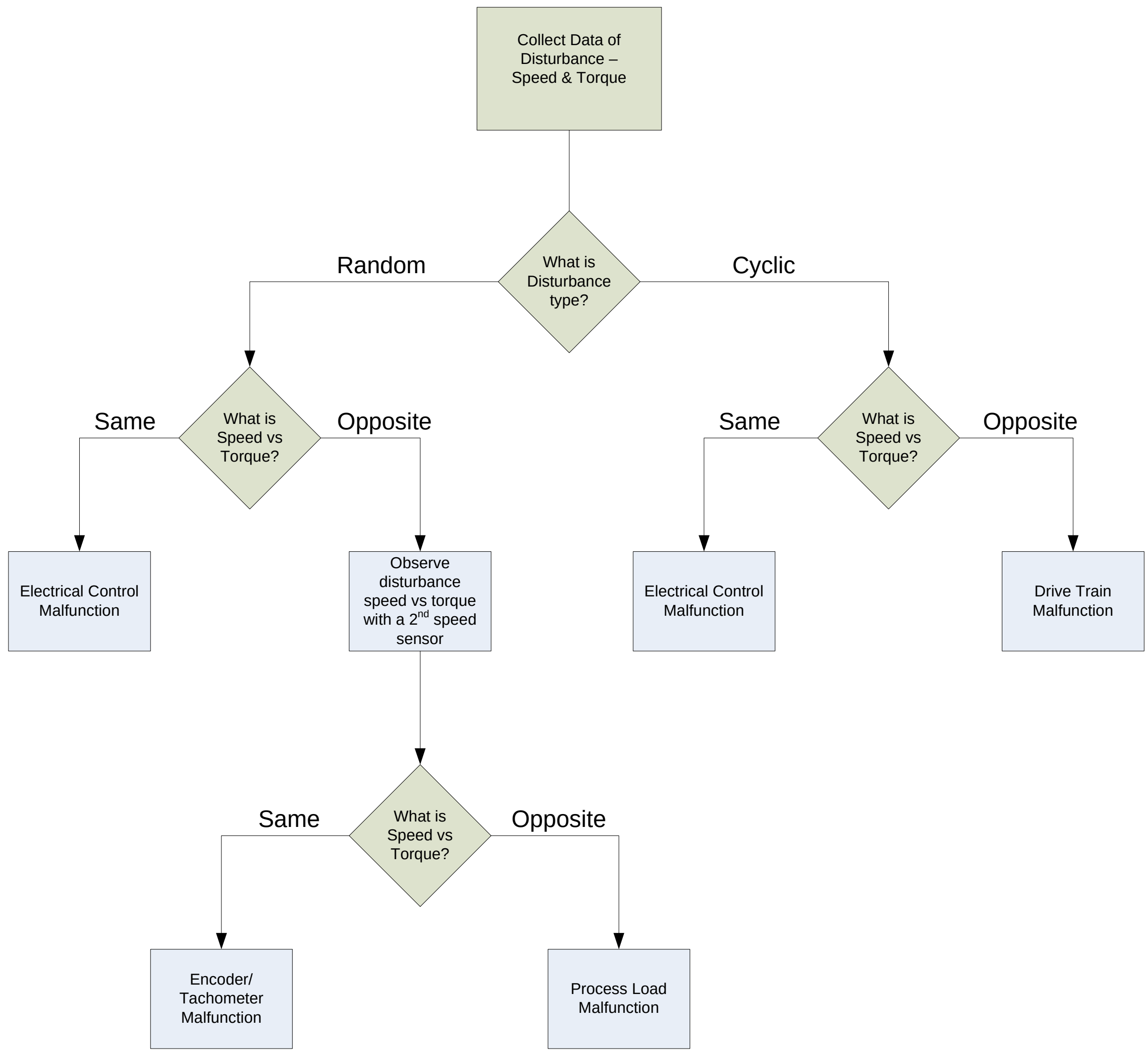

Fig. 9 – Disturbance Analysis Block Diagram