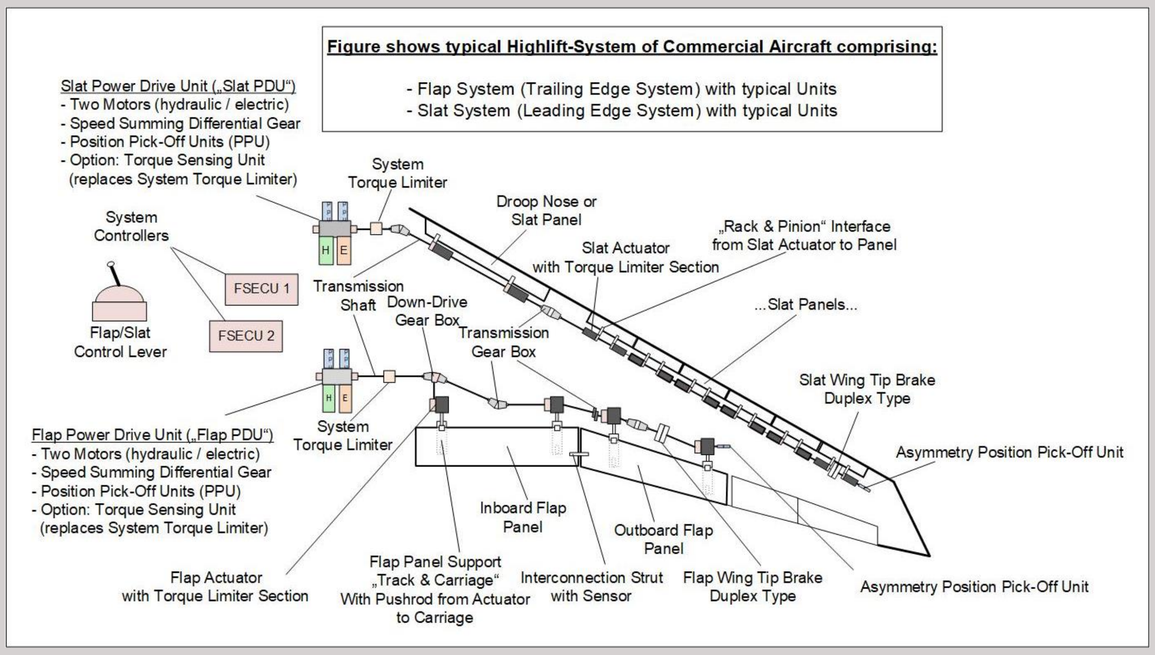
Disconnect-Detection and Overload-Prevention Sub-System (DLDS)
For Highlift Systems of Commercial Aircrafts
According to German Patent Nr. 10 2019 114 463 B4

Details given in Extended Abstract

Aircraft-System-Engineering-Service

Introduction:



Disconnect and Overload Detection Sub-System (DLDS) according to German Patent Nr. 10 2019 114 463 B4:

Covers following Failure / Abnormal Operation Cases:

1.) Disconnect of Load Path from Actuator to Panels:
Possible reasons of Disconnect:
Rupture of mechanical parts from Actuator to Panel („free-wheeling")
Rupture of mechanical parts inside Actuator at output („down-drive-disconnect-whilst-through-drive-maintained")

2.) Overload of Load Path from Actuator to Panels:
Possible reason of Jam:
Foreign Object jammed in load path from Actuator to Panel

Existing (Conventional) Technologies:

For Flap Systems:

1.) Disconnect Prevention (examples):
- Interconnection Strut between inboard and outboard Flap Panel
- Position Measurement of Flap Support
- Load Measurement of Pushrod

2.) Overload Prevention:
- Mechanical Torque Limiter at input shaft of Actuator

For Slat Systems:

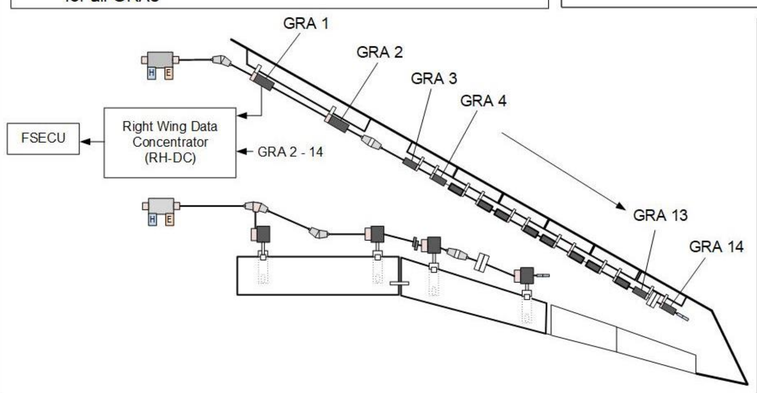
1.) Disconnect Prevention (examples):
- Lanyard type: Wire through all Panels
- Position measurement of rack („Multiple Target")
- GRAs certified as „Damage Tolerant"

2.) Overload Prevention:
- Mechanical Torque Limiter at input shaft of Actuator

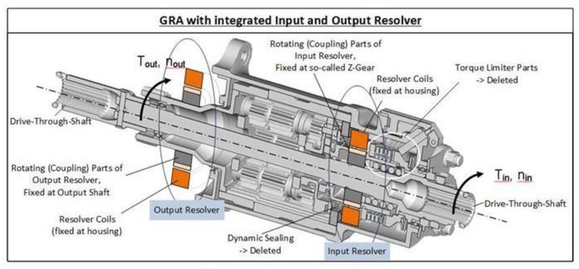
Possible Solution according to Patent, Example: Slat System with Rotary Type Actuators:

Proposed System and Unit Design for DLDS:

- According to Patent, compliance of Geared Rotary Actuator (GRA) ist used as parameter for Disconnect Event and Load Measurement
- Each GRA is equipped with two Resolvers in order to measure distorsion under load
- Data Concentrater proposed in order to save cable weight. Comprises generation of distorsion $\Delta\phi$ and monitoring for all GRAs



GRA with integrated Input and Output Resolver



Precise and robust Resolvers are proposed from Swiss Company:

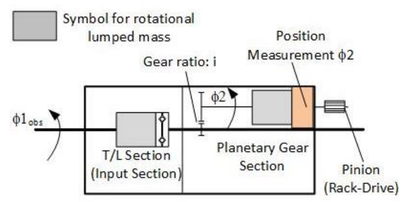
admotec Advanced Motion Technology

Single-pole and multiple-pole types available with large in-service experience (hydraulic motors):

Typical precision:
Single-pole type: ≈ 1°
Multiple-pole type: ≈ 0.1°

Typical MTBF, reached on hydraulic motor application: ≈ 8 Mio. FH

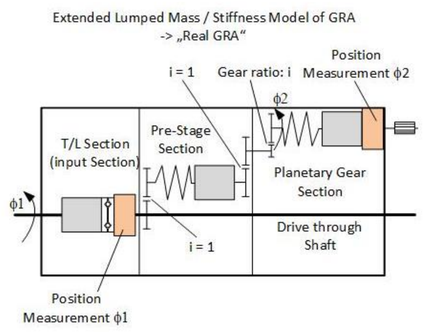
Principle of Rotational Distortion Measurement via „Observer" Model



„GRA Observer" Model:
- infinite stiff GRA asumed
- Rotational Position Measurement $\phi 2$ at output only

-> Position at input ($\phi 1_{obs}$) can be „observed" at any time by :

$$\phi 1_{obs} = \phi 2 * i$$



„Real" GRA, two Measurements:
- Position Measurement ($\phi 2$) at output
- Postion Measurment ($\phi 1$) at input

-> Distortion $\Delta\phi$ can be determined by residuum between measured $\phi 1$ and observed $\phi 1_{obs}$:

$$\Delta\phi = \phi 1 - \phi 1_{obs}$$

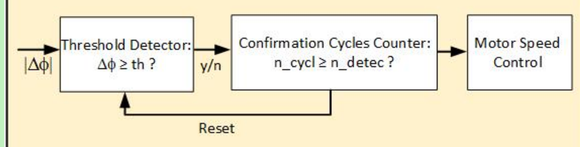
Hence:

$$\Delta\phi = \phi 1 - \phi 2 * i$$

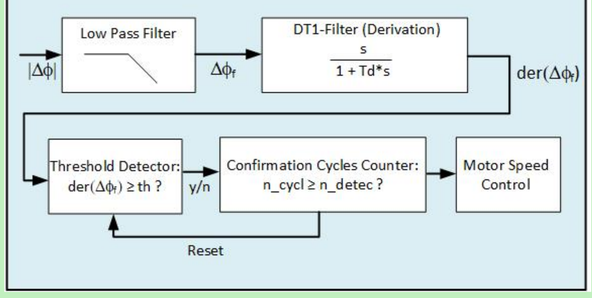
- positive values of $\Delta\phi$ for compressing loads over GRA
- negative values of $\Delta\phi$ for tensile loads over GRA

Two Monitors are proposed to detect Overload and Disconnect

Overload (Jam) Monitor:



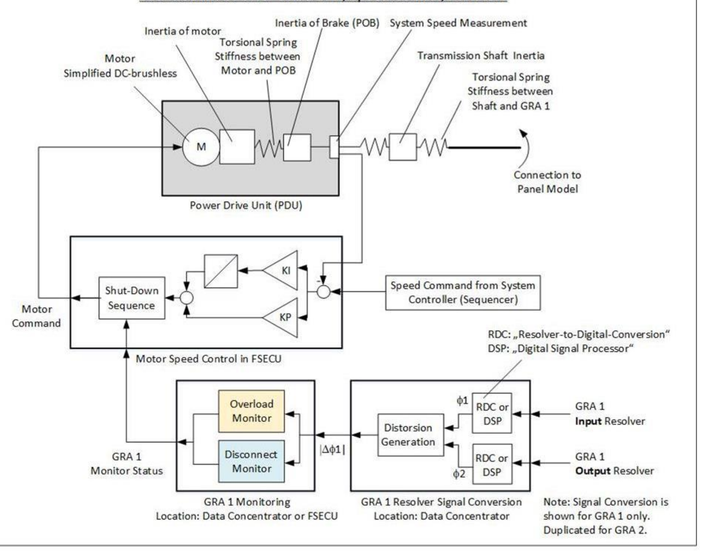
Disconnect Monitor:



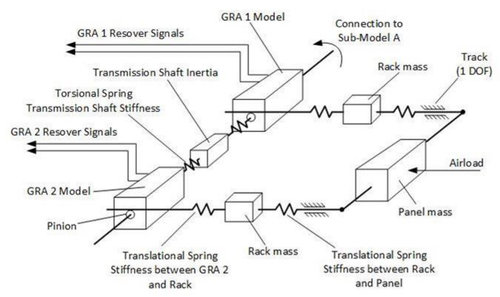
Proof-Of-Concept – Simulation Model and Results:

Establishment of dynamic simulation model in order to proof the concept of the Patent.
The Model consists of two Sub-Models A and B

Sub-modell A: Power Drive Unit, Speed Control, Monitors



Sub-Model B: Slat Panel Spring-Lumped Mass Model with Resolver Signal Outputs



Further Information regarding Simulation Models:

Speed Control Frame Time (sample and hold):	2 ms
Monitoring Frame Time (sample and hold):	2 ms
Speed Sequence at start-up (Slats extending):	from 0 to 1000 rpm within 2 s
Nominal Transmission Speed:	1000 rpm
GRA Compliance Input to Output:	1,7 Nm/rad
Type of Speed Control:	PI-Controller
Overload Monitor:	Threshold $\Delta\phi$: 117° / 5 Confirm.
Disconnect Monitor:	Threshold der($\Delta\phi$): 300 °/s / 5 Confirm

Three Cases have been checked:

Jamming of Rack 1 (due to foreign object):

Slat Operation: Extension
PDU Speed: Nominal, 1000 rpm
Failure Insertion: Lumped mass of Rack 1 locked

Overall Result: Successful – covered by Jam Monitor
Loads within expected range

Rupture of Load Path from GRA to Panel:

Slat Operation: Extension
PDU Speed: Nominal, 1000 rpm
Failure Insertion: Spring Stiffness of Rack 1 set ot 0

Overall Result: Successful – covered by Disconnect Monitor
Loads within expected range

Internal GRA Failure: Down-Drive-Disconnect Whilst Through-Drive Maintained:

Slat Operation: Extension
PDU Speed: Nominal, 1000 rpm
Failure Insertion: Spring Stiffness of GRA Model Pre-Stage set to 0

Overall Result: Successful – covered by Disconnect Monitor
Loads within expected range

Proof-Of-Concept – Comparison of principal MTBF Numbers:

Comparison of MTBF Numbers has been carried out, between:

A.) Slat System with conventional torque limiters / no disconnect detection
B.) Slat System equipped with DLDS

Affected units considered only, no full Highlift System Evaluation
DLDS with simplex resolvers and simplex data concentrators

Results:

System A MTBF: 67.000 FH
System B MTBF: 26.000 FH

„Budget" for system A for included disconncet detection functionallity: 42.500 FH