Mechatronics for elevator installers and drive technicians, Part 1 and 2

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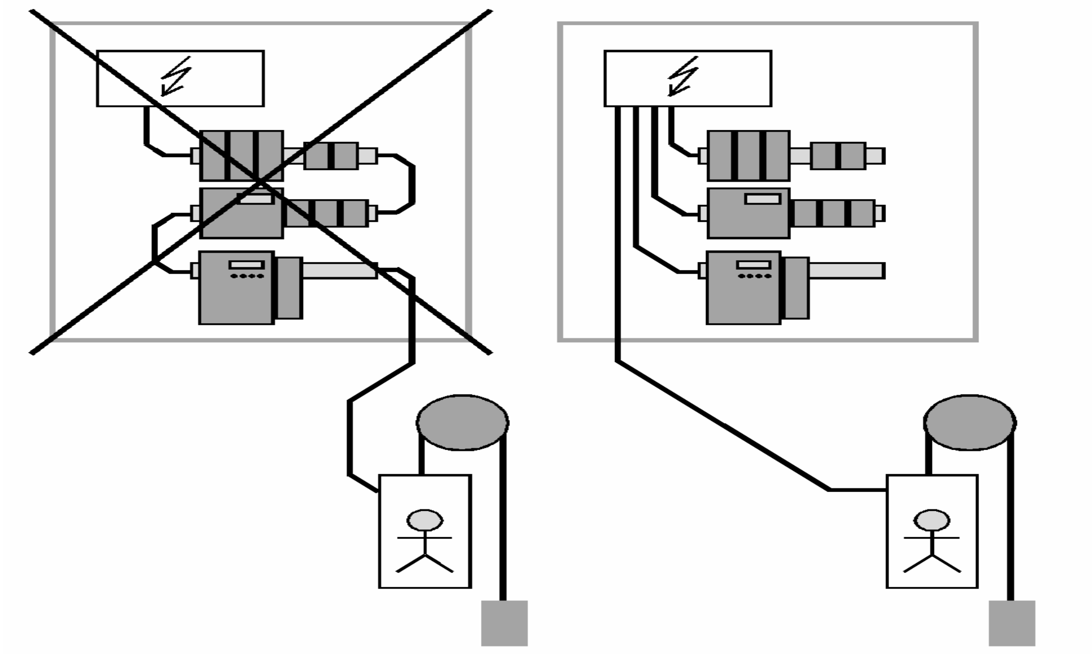
There is no question today that professional and technical demands in the field of elevator and conveyer technology have grown tremendously in the past few years. The assembler, control system builder, gearing engineer and motor manufacturer are expected to possess a measure of basic knowledge, the extent and breadth of wich may not be underestimated, in the fields of mechanical engineering, electrical technology and electronics. It is for this reason that a new career profile has come into being, that of the mechatronics engineer. Regrettably, no branch of vocational training wich would qualify "elevator assemblers" has as yet been recognized; thus an apprenticeship as a mechatronics technician would be seen as the closed alternative.
The following article is intended to provide insights into some of the important fundamentals of drive technology since, in elevator and conveyer engineering, unexpected results occur again and again if the "mechatronics technician" lacks a certain degree of experience and fundamental knowledge.

The switchgear cabinet

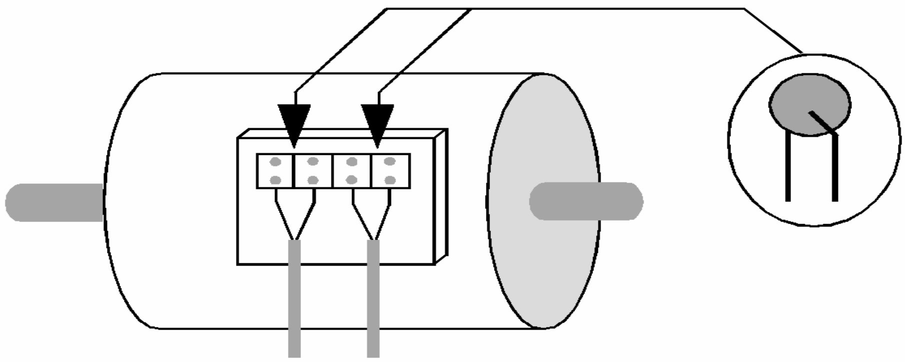
The first errors are made even before tha switchgear cabinet is assembled. Neat and tidy wiring provides no guarantee that the controls will operate entirely free of interference (EMC/ESD). Satisfying the rules wich apply here is, in fact, quite simple:

- Provide a "fresh" operating voltage supply for each bus in the swithgear cabinet. To do so establish a so-called star point inside the switchgear cabinet, near the incoming feeder for the power pack. Starting at this point, always route both the "+" and "-" or "neutral" and "phase" or all three phases from the supply point to the bus in question and to its using units (contactors, relays etc.). Never loop potential through several buses (and certainly not to the hall button, the car or the like), since the inductance in a line such as this can, under certain circumstances, be seriously disturbed by parallel switching events.



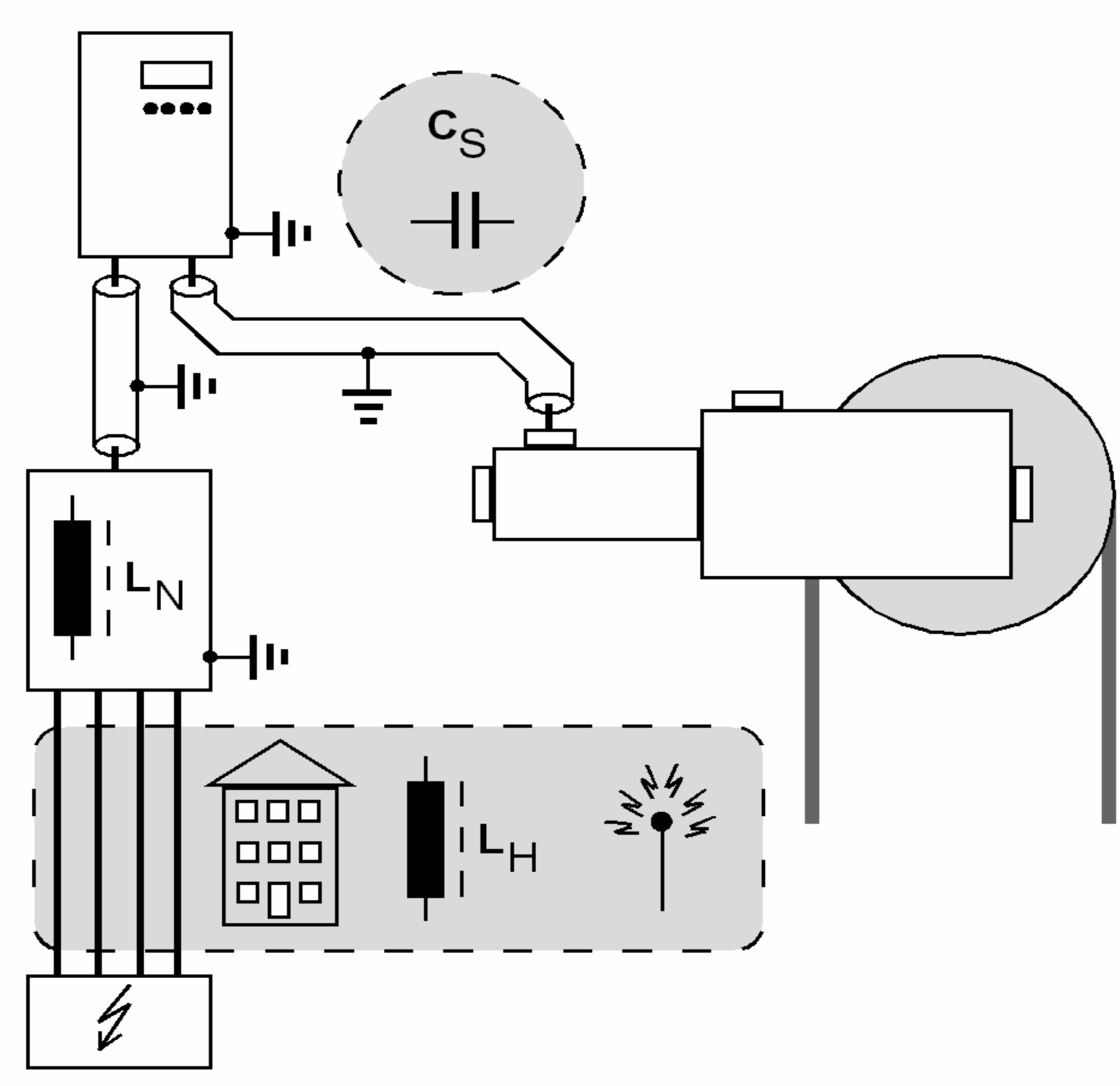
(picture 1)

- At a minimum provide interference suppression equipment for the coils in the motor contactors (main drive, door actuators) and at the braking relay. Here varistors, suppressors or RC circuits are suitable; tha manufacturers of such relays can usually also supply matching interference suppression devices. Free-wheeling diodes (for DC coils) are not entirely suitable since they can, under certain circumstances, unintentionally extend the relay breaking point. If, when using diodes, you also connect a resistance in series with the diodes, the value for wich should correspond approximately to ohmic value for the relay coil, then an acceptable switching period will be attained with good pulse suppression.
- The greatest source of disturbance (as regards so-called click interference) is the coil built into the braking solenoid at the drive itself. This interference is returned to the swithgear cabinet as a high-inductance kick.back voltage as soon as the brakes engage at the end of the trip. Unfortunately the manufactures of these brakes, even today, do not install the appropriate interference suppression devices near the brake coils as a matter of routine. These are essentially the same suppression circuits as those used for relay and contactor coils. Varistors are used as a rule today since these extend brake actuation times by only a negligible period. What is important is that these varistors be slightly over-dimensioned since insufficient power-handling capacity will bring about undesirable aging (which will, over time, shift the response voltage at the varistor upwards, an undesirable effect). The varistor must be attached directly to its coil or its connections. Varistors mounted directly at the rectifier are completely ineffective so that they can be omitted without any reservations whatsoever. It is also important to know that brakes operating with AC current (instead of DC) have in the meantime been placed on the market. These are equipped with special electronics installed in the junction box at the brakes. These electronics make available an active rectifier wich regulates in an ideal fashion the excitation voltages needed for activation and holding while at the same time suppressing interference at the coils.



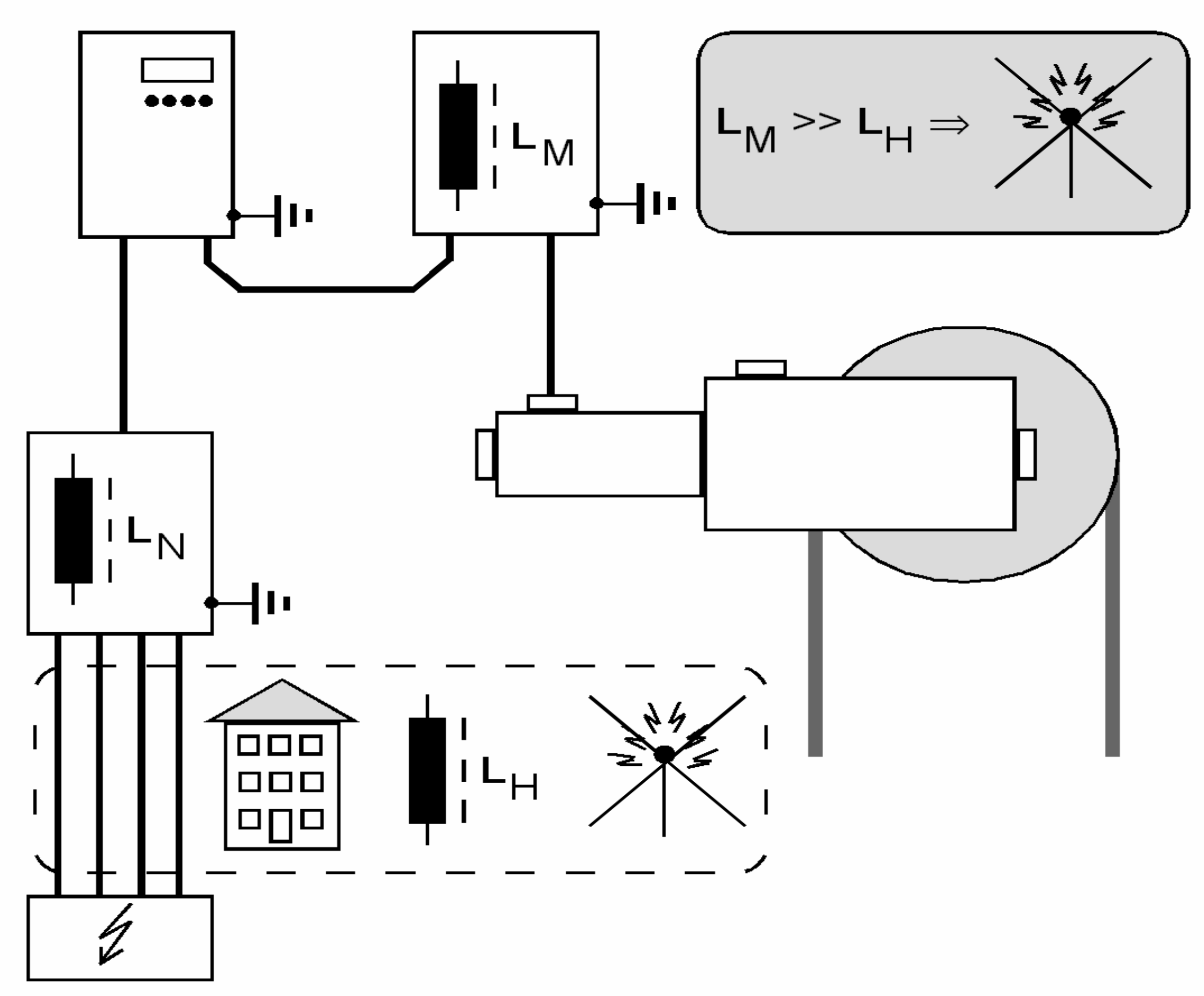
(picture 2)

- A further source of interference is the frequency inverter wich is customarily used. Line filters and shielded cables are usually employed in order to maintain the required level of interference supression (normally class "B"). An aspect wich is often underestimated here is that, if not properly installed, the motor cable shielding itself can under certain circumstances boost instead of reduce the interference level. The shielding braid must without fail be in full contact, over a broad surface area, at both ends of the cable. Special-design type PG, heavy-gauge conduit grommets are available, as are special grounding clamps for the switchgear cabinet, designed to accept the shielding braid. Since the capacitive currents at the shielding can be quite large (up to several amperes, depending upon the dU/dt value), the grounding system must exhibit low resistance. This is however, not always the case for machine rooms located above the shaft; here interference passes through the grounding cable and the hoistway as freefield emission.



(picture 3a)

- The interference signal will seek the point with the greatest inductance and will radiate its power freely there. This is why some systems and control systems – in spite of shielded motor cables – are subject to sporadic failures. Far more effective is inserting a serial motor filter between the frequency inverter and the motor.



(picture 3b)

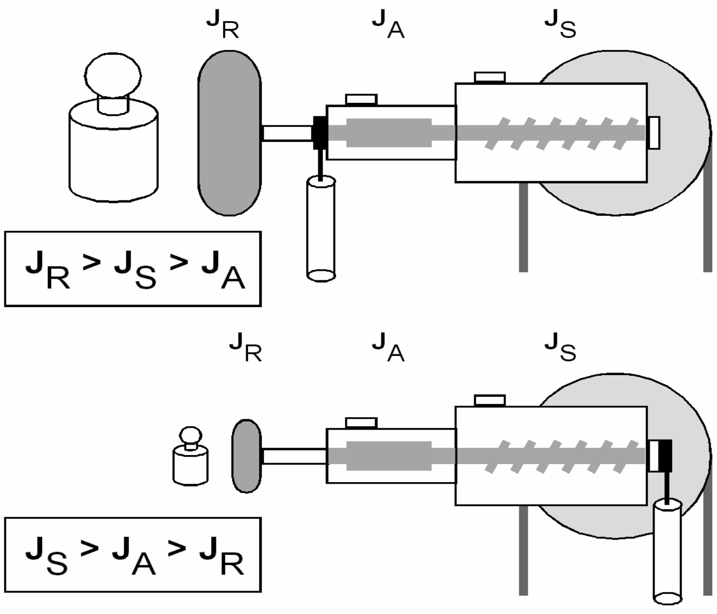
- Since an artificial emission inductance is set up by using a high-cut interference filter of this type within a closed housing, not only will the dU/dt generated at the system be easy on the motor; capacitive reactions (a disadvantage of the shielded motor cable) will also be completely suppressed. Interferance suppression on the line side can thus be effected with considerably smaller currents going to ground. With proper design the shielding for motor cables at a length of up to 10 m can be eliminated. The dissipated currents are, in addition, so low that standard "FI" ground fault interrupters can be used to enhance system safety (this is very important in regard to the power distribution panel used during the construction phase). Particularly when upgrading existing aluminum-silicon alloy motors, damage to the windings (usually at the end winding) will appear after two years, at the latest, if no motor filter is employed. Modern asynchronous motors are less sensitive in this regard, especially when using brand name motors with phase separation, "F" class conductors and vacuum impregnation fot the stator core. Caution must, however, be exercised when dealing with gearless winches or planetary gears in combination with synchronous motors. These designs have, by nature, very little leakage inductance and are thus very "hard." Consequently an extreme dU/dt value will also generate a high dU/dt value wich – in spite of quality windings – can result in motor failure if no motor filter is installed.
- Damping of the fifth resonance in the network should today in fact be standard technology. Often, as a result of cost considerations, one attempts to do without the minimum required equipment. Here a line choke matched to mean energy

requirements (for example, 35A, 3-phase, 0.7 mH at 4% short-circuit voltage) is an economical solution. Active, regenerative cos φ power factor correction is usually to expensive.

- One opinion continues to persist in regard to the use of shielded cables. The fact that shielded cables installed for the motor or braking resistances must always be connected at both ends has already been explained. But this also applies to all other lines (e.g. interfaces and comparable bus connections, leads to rotation signal transducers, tachometers, resolvers and pulse counters). The only exceptions here are ananlog signals in ranges of from 0V to 10V or from 0 (or 4) mA to 20mA; here the shielding is connected only at the end nearest to the source. The reason is that these are "slow" signals in wich a line hum loop would be far more disturbing than an injected RF interference pulse. All the other signals are either in the "digital" category or are, at the least, present as typical differential signals (rotation transducer); here the presence of line hum will be of no importance. Of significance here, however, is shielding against Rf interference in the upper MHz range wich is swept along with other voltages into the system; here shielding wich is attached at one end will act as a delay element. Consequently shielding connected at one end thus can, under certain circumstances, cause a reflection from the free end of the shielding and this can even lead to self-reinforcement of the interference level. We will discuss this problem in detail in the following section on rotation transducers.

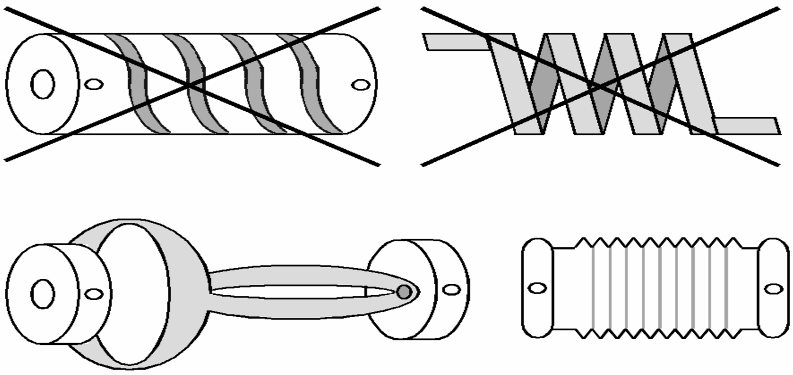
The rotary position transducer at the motor

The next group of errors is usually built in while the lift machinery itself is being manufactured. In spite of some excursions into the field of "transducer-less" regulation for electric motors, one can quickly determine that even the most economical transducer system operates more safely and reliably than any regulation technology wich does not include feedback foe the current rotation value. Only those slowrunning conversions for existing equipment (now drawing to a close) wich presents difficulties in attaching transducer systems should be operated without rotation transducers. The installation site, the coupling for the transducer, the type of transducer and its wiring are often matters wich are, regrettably, underestimated.



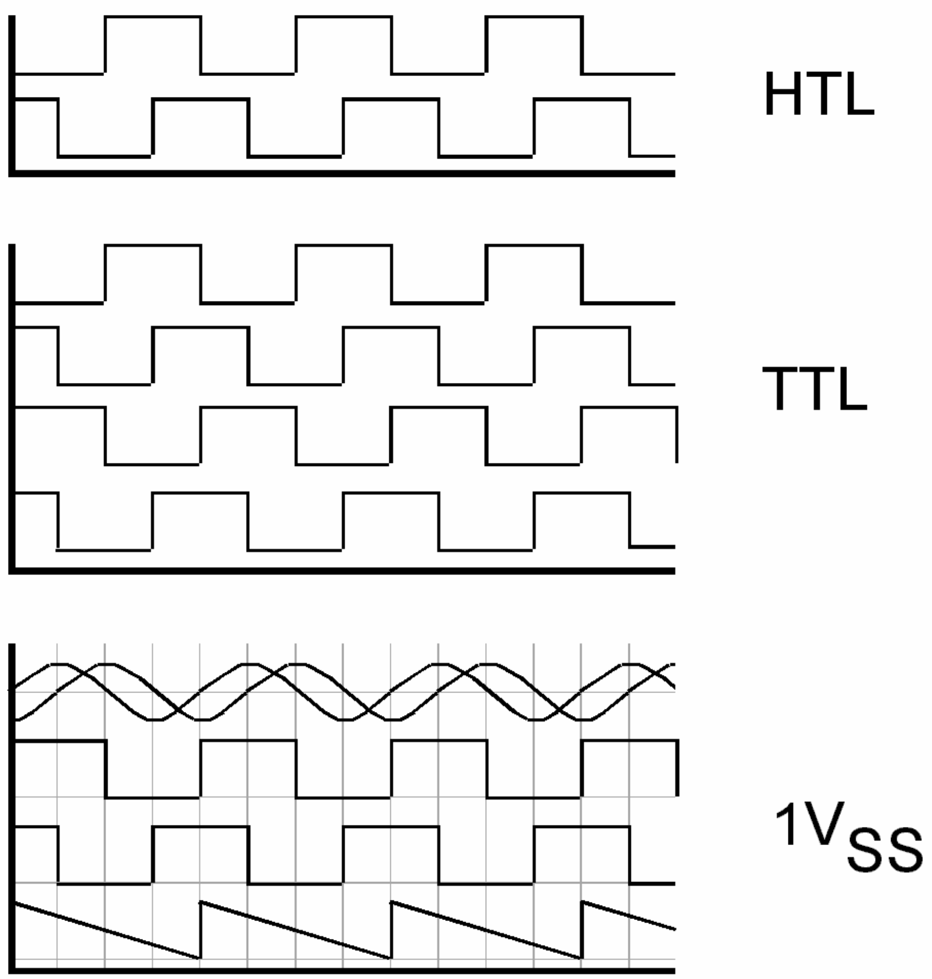
(picture 5)

- Seen from the mechanical point of view the rotation position transducer should always be situated at the site with the greatest inertia and at the same time that with the highest rotation speed (thus at the motor and not, for example, at the gearing output shaft). Where conversions of existing equipment are to provide for feedback regulation it often – contrary to widespread opinion – does not make sense to remove the massive cast handwheel if the rotation transducer is to be attached at this end of the shaft. In contrast to U/f frequency inverters (without momentary value feedback), a field-oriented system wich regulates power will have no problems with this "flywheel mass." New systems often exhibit very low inertia in the motor and this is certainly of interest in regard to energy consumption when accelerating and decelerating the car; from the regulation technology viewpoint, however, this can conceivably result in very rough system operation since the motor dynamics are to high for the car system with its high inertia values. Since in modern worm gear drives the worm itself usually contributes more inertia than the motor`s armature (in conjunction with the plastic handwheel often used today), the rotation transducer should be located at the end of the worm shaft and not at the end of the motor shaft. By contrast, the motor`s armature is the "heavier" component in hypoid or planetary gearing and thus mounting a hollow-shaft transducer at the end of the motor drive shaft is standard. In regard to handwheels located further outboard it is essential to note that plastic models and steel castings are permissible but that handwheels made of aluminum should never been employed since these exhibit an unfavorable *eigen* resonance and begin to make noise at certain speeds. If the handwheel installation point or its material is not taken properly into account, then the amount of gain wich can be set at the speed regulation unit will drop sharply, making the drive to "soft" and unstable (travel comfort is degraded) or the drive will generate a loud hum.
- The mechanical coupling for the rotation transducer is also a very critical component in the feedback control system. Experience has shown that – in spite of



(picture 6)

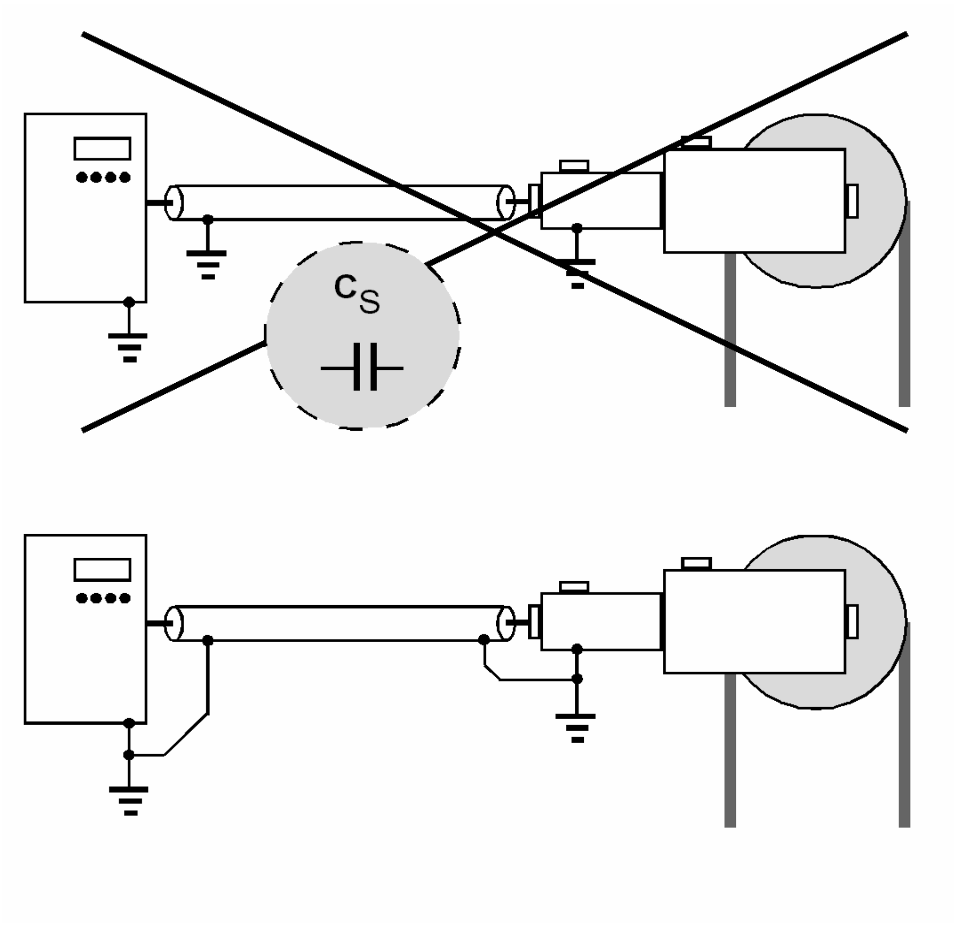
- proper consideration of the installation site and the interia involved – the system may exhibit a tendency to poor regulation if the material and the design are not properly matched in the coupling between the transducer system and the motor. The rotation transdicer coupling must not, for example, exhibit any *eigen* resonance within the range of the regulation cycle. It is for this reason that no couplings may be used wich act like a spring along the torsion vector. Here again – as for the handwheel – the choice of materials is quite decisive. One should never use couplings wich are manufactured as one piece from aluminum or any similar lightweight metal or alloy and where rotational play is achieved by notching at the circumference (helical principle) since couplings of this type will resonate. This can be aggravated if one neglects the fact that the ends of the shaft – depending upon the location of the fixed bearing – will expand in response to heating and thus compress the coupling to the extent that all rotetion play is eliminated; as a consequence, the ball bearings in the rotation transducer will be overloaded. Also unsuitable are couplings wich resemble coiled sreel springs (often used in simple geared motors for conveyer technology), since their *eigen* mass is to great and, in addition, they have a strong tendency to resonate in the torsion direction. Here the best coupling is at the same time the most economical one: a simple rubber tube or hose (with textile reinforcement) held by two hose clamps has given very good results in test configurations. The coupling with the crossed "yellow" plastic stripes (Periflex principle) also yields acceptable and economical results. The reason is simply that oscillation decays aperiodically and very quickly whenever its excited, since damping is considerable. An even more perfect solution – but one wich cannot always be mounted in the configuration at hand – is a hollow-shaft transducer; this is, however, usually somewhat more expensive.



(figure 7)

- The type of rotation position transducer is also quite decisive for travel comfort, safety (amenability to monitoring) and motor noises (regulation resolution). That is why the three most common types of rotation transducers are to be explained and examined at this juncture. The oldest system is the "HTL" transducer with only two channels, A and B, and wich operates at very high votages (10 to 30V as both the operating and output voltages). One should not fail to mention at this point that this type of transducer no longer represents the state of the art and must in all cases be avoided – at least in new systems or when retrofitting. The reasons are that it is difficult to monitor this type of transducer for error, that the transducer is susceptible to interference (the output is not a differential signal) and that it draws a large amount of power (connected load). Somewhat more modern are the "TTL" rotation position transducers wich utilize four channels (A+,A-,B+,B-) and wich deliver a level of about 4V at a low-impedance output with offset of about 90°. These transducers are resistant to interference and can readily be used as their operating voltages are typically between 5 and 15V.The state of the art, however, is atype of transducer wich also outputs four channels offset by 90° but wich, at the customary 5V operating voltage, emits four 1 Vpp sinusoidal analog signals. The advantages of this transducer are that it can be monitored for possible failures when at a standstill, that it is very resistant to interferance, that despite alower number of counting stripes it provides very high resolution for the momentary value, and that is suitable for operation with long leads. Modern frequency inverters are equipped with acombination of basic pulse and tangent evaluation wherein, for example, an effective useful resolution of 65536 increments per revolution can be extracted from 1024 stripes per transducer revolution. (This resolution is better by a factor of 16 when compared with a 1024 TTL transducer employing the maximum possible flanktriggered pulse quadrupling or better by a factor of 64 when compared against a type 1024 HTL transducer without pulse multiplication). Since the basic resolution level no longer need be so high, the glas disk wich is used (in an optical transducer) is also more economical than that used in a comparable TTL system wich is at present available as a TTL serial transducer with a maximum of 10,000 stripes. particularly in conjunction with gearless technology and its extremely slow-running motors (0 to 100 rpm being the typical operating speed range), the use of 1 Vpp transducers is an absolute necessity (2048 stripes per rotation will suffice). Rotation transducers of this type are also available as combined systems with a supplementary, 13-bit absolute value transducer channel for gearless synchronus motors (with an "SSI" system being given preference). The synchronous motors, wich usually run at considerably higher speeds, together with downline planetary drives use resolver systems instead which can then be converted back, by calculation, to a 1024-stripe system.

- Grounding and shielding at the transducer housing and transducer cable are again and again topics of discussion when comparing textbook theory and actual, practical experience. There are still rotation transducer designs on the market in which the transducer cable shielding is not connected with the transducer housing. This is a serious flaw and is based on misunderstandings in regard to possible power flows inside the ball bearing at the transducer. There is no danger in this regard where there are correct electrical and mechanical connections between the transducer and the motor. Transducer shielding which is not connected will, by contrast, damage and destroy the rotation transducer electronics over time since the signal amplitudes will become to far removed (capacitively) from the operating voltage. Thus it is necessary to ensure that the transducer cable carriers measurable motor ground potential. Here two conditions will have to be satisfied. There must be a conductive connection between the transducer housing and the motor housing (and thus with the motor`s ground potential). In this context it is necessary to keep in mind that – when using hollow-shaft transducers, for example- the torque support should never be installed so as to be insulated.



(figure 4

The situation is that if the transducer housing is insulated, compensation currents will actually flow through the ball bearing at the transducer disk, causing unintended erosion at the bearing. The transducer cable should, for its own part, be connected with the transducer housing so as to be conductive and thus indirectly connected with the ground potential for the motor housing. Thus one can be sure that any peak potentials which are present will have no effect on the useful signals in the channels. In addition, a suitable cable design should be provided for the transducer`s useful signal. Here it is absolutely necessary that twisted pairs, approved by the manufacturer, be used (and thus no “PC printer cables“). In addition, careful attention should be paid to clean and tight solder or crimp connections.