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Application of Motors in Power System Protection Devices

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Abstract: In a modern power system, the role of protection is very crucial. The devices used for protection are termed switchgear. There are two basic types of protection primary protection & secondary protection. The main purpose of these devices is to make & break the circuit. The contacts are moved with the help of motors. Normally we use Fractional Horse Power (FHP) Motors for this type of application. The criteria for evaluation for the motor is more important as compared to actual performance. This paper highlights the role of motors in switchgear application

Keywords: Power System Protection, Motors, Switchgear

1. **Introduction** Motors are used for several applications in switchgear. Switchgear mainly constitutes circuit breakers & disconnectors. Operating mechanisms are used for moving the contacts to make & break the circuit. Energy to drive contacts is generally derived from the motor. The motor could be directly driving the contacts or store the energy in various forms which could be released to drive the contacts. Motors experience different loading patterns depending on where & how they are used. The motors used for switchgear are required to operate seldom. However, they must perform their function when required. This makes the motors very special as they are lying idle for most of their life. Special care must be taken to avoid aging when not in use. Motors experience, as in general use, mechanical, dielectric & thermal stresses. However, as they have to perform for a very short time, they are designed for a short-time rating. Switchgear is generally used outdoors. Motors, though housed in protected cabinets, experience relatively harsh environments. Recent developments in the operating mechanisms use servo motors which are directly used to drive the contacts of the circuit breakers. The energy required to drive the motor is stored in capacitors in such applications.

2. **Disconnectors:** Disconnectors have arms moving horizontally or vertically depending on the type of Disconnectors. The angle of the rotation is approximately between 90 to 180 degrees. Rotation of the arms is achieved within 10 to 15 seconds through gears & linkages. Motor RPM is selected based on the gear ratio. The torque requirement is accordingly selected. Disconnectors motors are required to rotate in a reverse direction such that the Disconnectors can be closed & opened using the same motor by reversing the electrical connection. These motors have generally constant torque requirements. However, during the beginning of the operation, the motor has to accelerate the moving mass of the Disconnectors. In extreme applications of ice loading, the motors should be capable of breaking ice & making the movement possible. For such applications, motors should also have high starting torque. Figure 1 shows disconnectors with ice loading.

Figure 1 Vertical break disconnectors with ice loading under test

For DC voltages, compound motors are used for disconnector application. A compound motor has a somewhat higher starting torque than a shunt motor of the same rating. For AC voltages, motors with high starting torque

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characteristics are to be used. Figure 2 shows a comparison of dc shunt motors & compound motors. Compound motors are used as the disconnectors have constant torque requirements except during starting. For designs where contact insertion is direct, there will be a momentary high torque requirement. For example, double-break disconnectors will experience high torque requirements while insertion of the contacts. Compound motors offer an ideal solution to such application.

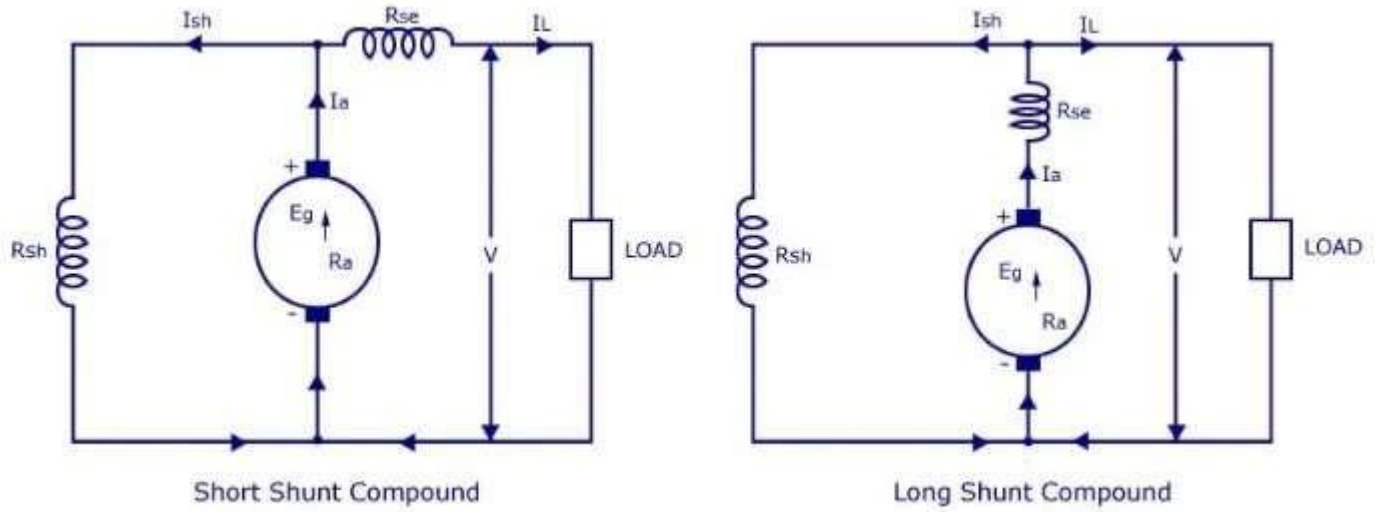

Figure 2: Characteristics of DC Motors

For most of the applications where the disconnectors do not experience ice loading, the starting torque requirement is not very high. For such applications, permanent magnet motors are also used. These motors can be overloaded to as high as 150% load. Many utilities use 3 3-phase AC motors for the disconnector application to avoid the large size of the battery. AC motors also facilitate the commissioning of the disconnectors when battery power is still not available. The drives used for the disconnectors are defined by the maximum torques they can deliver on the shaft to be connected to the disconnectors. The torque could be say 50 Nm & 100 Nm. The torque at the shaft can be increased by reducing the friction in the gears & transmission. Such type of solution is adopted to standardize the motor. The other option could be to use a larger motor & use same type of gears & transmission. This will increase the size of the motor & also of the operating mechanism.

3. **For Circuit Breaker Operating Mechanism:** The circuit breaker operating mechanism uses different methods of storage of energy to be released when the operation is to be carried out. The modes of storage could be spring compressed air or gas depending on the type of mechanism. Present-day motor is also being tried out to be directly mounted on the shaft of the circuit breaker pole. Servo motors are used for such applications. Such motors derive energy from a capacitor bank & the energy is fed through the electronic circuit to deliver desired energy to get desired travel characteristics.

4. **For Pneumatic Operating Mechanism**

Compressed air is used as a storage medium for the Pneumatic operating mechanism. Compressors are used for compressing air. Such motors normally experience compressor application duty. 3 phase AC motors are generally used except where very high reliability is required. For such applications DC motors are used & the power is derived from storage batteries. Indian Railways use DC motors. Compressors are generally mounted outdoors with a simple canopy-type enclosure. The motors experience out-doors weather conditions. The load is pulsating type & hence if the pulsation is not reduced, the motor draws more reactive power. In such cases, the motor may draw more current than the rated current. Pulsation is reduced by increasing the moment of inertia of the rotating parts like the pulley. Such motors, like any application have a short time rating. The compressor is run for the First filling of the air receiver, to replenish the air consumed during the operation of the circuit breaker, a Small leak is provided to ensure that the motor runs at regular intervals such that the insulation of the motor is warm as compared to the surrounding temperature. This ensures the soundness of the insulation.

5. **For Hydraulic Operating Mechanism**

Hydraulic mechanisms used compressed N2 at very high pressure. Some designs use springs to store energy & the energy is transmitted using hydraulics. For both applications, hydraulic pumps are used to drive the fluid

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from the low-pressure zone to the high-pressure zone. The motors have to start against high pressure. The application is a short-time rating. In case of leakages in the hydraulic system, the motor may have to run more often.

6. For Spring Operating Mechanism

Springs are used to buffer the energy required to operate the circuit breaker. Generally, universal motors are used for charging the spring(s). This is because the torque requirement for charging varies as the lever angle changes with the charging of the spring & opposing force from the spring also increases as the spring gets charged. The motors are generally designed for short-time rating to deliver high instantaneous power. Spring drives are generally mounted on the circuit breaker pole. Every time the pole of the circuit breaker operates, it experiences heavy vibrations going as high as 10 to 15 g acceleration depending on the way it is mounted & the energy of the operating mechanism. The motor starts running as soon as the CB pole is operated (closed). Hence, it experiences shocks when it is running. This poses a very special condition which is normally not experienced when the motor is tested as per standard. Hence, testing of the motor in actual application is only a good way to qualify. Indian utilities provide AC power supply to the motors to reduce the battery size. It is experienced that the quality of the AC power supply is very poor & regulation is bad. The motor experiences more current than they are designed for & hence brushes burn out very fast. This gives a higher failure rate for the motors. Compared to this, DC motors give better performance as the voltage from the battery is stable & motors are not abused due to power quality. It is recommended to use DC power, particularly for the higher energy mechanisms for higher voltages.

7. Motors Drive

Motor drives are a recent innovation. The Servo motor is directly mounted on the shaft of the pole & the motor provides the required torque to achieve the desired travel characteristics. This is performed by computer-controlled power electronics which feed power to the motor from a capacitor bank. The travel speed is constantly monitored & the computer depending on the feedback decides the power input to the motor. These drives are still not widely used due to the costs. However, they give the best possible solution when one needs a very precise contact travel characteristic.

8. Testing of Motors

The operating mechanisms of the breakers are required to perform satisfactorily during a lifetime of around 20 to 25 years. When the equipment undergoes type testing, the operations are completed within a week to a month depending on the type of mechanism & the rating of the motor. Extra cooling of the motor & other components is permitted by the standard to avoid undue heating. It is experienced that the components of the operating mechanism fail more often during type tests as compared to routine applications. Motors experience spikes in starting current & voltage when the motor is switched off. Spikes of the starting current cause mechanical stresses on the winding & commutation system. Overvoltage cause the weakening of the insulation system. Special design care is to be taken to ensure rugged design

where combined mechanical, thermal & dielectric stresses are experienced. The circuit breaker is required to perform 10,000 operations & hence, the motor should give satisfactory function. The motor is one of the many components/ subassemblies that decide the satisfactory function of the CB. Hence for reliable operation of the CB, the reliability of the motor needs to be high as the reliability of the series system is the multiplication of the reliability of subsystems. Considering various subsystems of the CB, it is desired that the motor gives satisfactory performance for around 150,000 operations.

Conclusion

Motors employed for protection applications in power system applications have different requirements as per the type of device. For example, in the Oil Circuit Breaker mechanism of arch quenching is oil while in the vacuum circuit breaker arc quenching medium is vacuum so the motor required for both circuit breakers may be different for the same capacity. The level of stress depends on the type of usage. We can conclude that, the selection of the ideal motor for protection applications. For better operation of switchgear, the performance of motors is very important.

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