

MT & HT Voltages & Submerged Motors

TECHNICAL ANALYSIS REPORT

ON ELECTROMAGNETIC & EARTH LEAKAGE CURRENTS IN REFERENCE TO POSSIBLE SHOCK HAZARD TO LIFE FORMS IN WATER BODIES DUE TO SUBMERGED MEDIUM VOLTAGE MOTORS

Primary Objective : This report deals with analysing the probability of electrical shock hazards to life forms due to Submerged medium Voltage Motors / Pump Sets (3.3kV, 6.6kV & 11kV).

Brief Background : MV Motors are used safely on ground installations throughout the world & have been found safe in operation & protection. The unique condition in submersible motors is that the body of the motor is not mechanically connected to ground & is floating in the water body along with the Pump. The Motor body is earthed through an Earth conductor which is one of the 4 core cable supplying the Pump Motor with HT Power input (RYB+E). The analysis focuses on the following questions.

Q1. : The first question to be answered is: If a life form touches the body of the motor (which is the only accessible part of the motor), is it safe under all standstill, operating, normal, abnormal & Fault Conditions? Is it possible to design a suitable protection system for full safety to life forms under fault conditions.

Q2. : The second question to be answered is: If a life form comes in the Vicinity of the HT Motor is there any possibility of shock hazard due to all possible normal & abnormal conditions?

It is an important factor to remember that the entire protection system will still be land based & remote at the power source.

Similar but not identical conditions exist on shipboard high voltage equipment & underwater high voltage cables but they are operating with high safety & satisfaction with suitable protection equipment without hazard since decades.

Analysis :

A. Shock Hazards -

A life form gets an electrical shock if a current of certain magnitude passes through it. For the current to pass through a life form it has to be subjected to a potential across two points of the body. The magnitude of current which is safe for a life form can be very different for currents passing through of the body. However it is an established fact that a voltage gradient of 24V max is safe. According to the International Electro-technical commission, the human body has a resistance of approx. 1 kilo ohms in wet conditions and a current of more than 60 mA is considered lethal. This corresponds to 60 V potential across the life form both in positive polarity as well as negative polarity. Thus a 24 V peak limit is well within the IEC voltage gradient.

B. Sources of leakage voltages –

There are following possible sources of leakage voltages that can appear in the body of any live electrical equipment including motors, Cables, terminals etc.

1. Capacitive charging due to Capacitance of voltage carrying parts. Every insulating material has a dielectric constant which allows +ve and –ve induced voltage in the body.
..due to both the Stator as well as Rotor being submerged & short circuited with each other by water, Capacitive charge build up is nullified.
2. Magnetically induced voltages due to alternating fluxes generated by alternating currents.
3. Direct short circuit (*insulation failure*) or insulation degradation
4. Sparking in live parts leading to voltage surges
5. Switching surges during starting and stopping
6. Lightning strike

All these conditions are present in Low voltage submersible installations as well as high voltage submersible installations - only their magnitudes may differ and part of the analysis would be, to have a comparative study of severity in LV and MV submersible installations.

C Different conditions of operation

The comprehensive list of different operating conditions for shock hazard analysis is as follows.

1. Motor at standstill – Supply fully cut OFF
2. Motor in starting and accelerating condition.
3. Motor in running condition
4. Motor Normal stopping
5. Phase to ground Fault in Motor
6. Phase to Ground fault in supply cable
7. Single phase failure
8. Two Phase failure
9. Reverse phase sequence
10. Phase to Phase fault inside the motor
11. 2 Phase to ground fault inside the Motor
12. Phase to Phase fault in the supply cable
13. 2 Phase to Ground Fault in supply Cable
14. Arcing Fault

The above conditions can be safely taken care by MV Motor design considerations and suitable protective system.

A. Design Considerations

1. The emf per turn of the motor winding should be less than 24V. All magnetic induction circuits are single turn loops and the induced magnetic emf will be equal to the single turn volatge. Thus it becomes a safe design. – DPR-1.
2. The Motor body and terminal boxes including cable entry points should be fully sealed to avoid absolutely no ingress of water. – DPR-2.
3. Metal Oxide surge suppressors of suitable rating should be installed at the source side of the cable going to the pump. – DPR-3.
4. Earth Conductor size should be large enough so that at Full earth fault current the volatge from Pump to Land across the earth conductor should not be more than 24 Volts– DPR-4.

B. Fault detection and protection system Considerations

1. Automated pre-start 24V loop test for ensuring - Protection TPR1
 - a. Non-breakage of the cable and absence of arcing fault
 - b. Non-breakage of Earth wire and No loss of earth contact
2. Automated pre-start Insulation resistance check on Cable and Motor circuit. - Protection TPR2.
3. Sensitive Earth Fault protection - Protection TPR3
4. Sensitive short circuit current protection - Protection TPR4
5. Sensitive Earth Leakage - Protection TPR5
6. Earth wire break/loose detection circuit - Protection TPR6
7. Comprehensive Motor Protection - Protection TPR7

The entire operating conditions and fault conditions are mapped in Matrix form to elaborate the correct protection and monitoring scheme.

The Analysis and Mitigation Matrix (AMM) -This matrix maps all the operating conditions with all possible faults and also allocates the protection which ensures full safety.

e.g. E1 (TPR-NA) designates the condition E (Phase to ground Fault in the motor), The focus issue of Capacitive Charging of Motor Body is absent as fault has grounded the phase and hence the condition is incongruous (NA).

E3 (TPR-3) designates the condition E (Phase to Ground Fault in Motor) , The focus issue is Direct short circuit and the condition is mitigated by TPR-3, 4, 5, 6, 7.

	Focus Issue	1	2	3	4	5	6
	Operating Condition	Capacitive Charging	Magnetic Induction	Direct Short Circuit	Sparking Surges	Start Stop Surges	Lightning Strike
A	Supply Off	A1 (TPR-5)	A2 (DPR-1)	A3 (TPR-1) + (TPR-2)	A4 (DPR-3)	A5 (DPR-3)	A6 (DPR-3)
B	Starting Accelerating	B1 (TPR-5)	B2 (DPR-1)	B3 (TPR-3,4,5,6,7)	B4 (DPR-3)	B5 (DPR-3)	B6 (DPR-3)
C	Normal Run	C1 (TPR-5)	C2 (DPR-1)	C3 (TPR-3,4,5,6,7)	C4 (DPR-3)	C5 NA	C6 (DPR-3)
D	Normal Stop	D1 (TPR-5)	D2 (DPR-1)	D3 (TPR-3,4,5,6,7)	D4 (DPR-3)	D5 (DPR-3)	D6 (DPR-3)
E	Phase to Ground Fault in Motor	E1 (TPR-5)	E2 (DPR-1)	E3 (TPR-3,4,5,6,7)	E4 (DPR-3)	E5 (DPR-3)	E6 (DPR-3)
F	Phase to Ground Fault in Supply Cable	F1 (TPR-5)	F2 (DPR-1)	F3 (TPR-3,4,5,6,7)	F4 (DPR-3)	F5 (DPR-3)	F6 (DPR-3)
	Focus Issue	1	2	3	4	5	6
Operating Condition		Capacitive Charging	Magnetic Induction	Direct Short Circuit	Sparking Surges	Start Stop Surges	Lightning Strike
G	Single Phase Failure	G1 (TPR-5)	G2 (DPR-1)	G3 (TPR-3,4,5,6,7)	G4 (DPR-3)	G5 (DPR-3)	G6 (DPR-3)
H	2 Phase Failure	H1 (TPR-5)	H2 (DPR-1)	H3 (TPR-3,4,5,6,7)	H4 (DPR-3)	H5 (DPR-3)	H6 (DPR-3)
I	Reverse Phase Sequence	I1S (TPR-5)	I2 (DPR-1)	I3 (TPR-3,4,5,6,7)	I4 (DPR-3)	I5 (DPR-3)	I6 (DPR-3)
J	Phase to Phase Fault inside the Motor	J1 (TPR-5)	J2 (DPR-1)	J3 (TPR-3,4,5,6,7)	J4 (DPR-3)	J5 (DPR-3)	J6 (DPR-3)
K	2 Phase to Ground Fault inside the Motor	L1 (TPR-5)	L2 (DPR-1)	L3 (TPR-3,4,5,6,7)	L4 (DPR-3)	L5 (DPR-3)	L6 (DPR-3)
M	2 Phase to Ground Fault in Supply Cable	M1 (TPR-5)	M2 (DPR-1)	M3 (TPR-3,4,5,6,7)	M4 (DPR-3)	M5 (DPR-3)	M6 (DPR-3)
N	Arcing Fault due to Loose Connection	N1 (TPR-5)	N2 (DPR-1)	N3 (TPR-3,4,5,6,7)	N4 (DPR-3)	N5 (DPR-3)	N6 (DPR-3)
O	Earth Wire Break	O1 (TPR-5)	O2 (DPR-1)	O3 (TPR-3,4,5,6,7)	O4 (DPR-3)	O5 (DPR-3)	O6 (DPR-3)
P	Earth Resistance High	P1 (TPR-5)	P2 (DPR-1)	P3 (TPR-3,4,5,6,7)	P4 (DPR-3)	P5 (DPR-3)	P6 (DPR-3)
Q	Earth Wire Loose	Q1 (TPR-5)	Q2 (DPR-1)	Q3 (TPR-3,4,5,6,7)	Q4 (DPR-3)	Q5 (DPR-3)	Q6 (DPR-3)

Conclusion:

There is NO additional hazard by increasing the voltage from LV to MV in a submersible / submerged system.

In fact in properly designed yet poorly maintained Dry Installed LV or MV motor incase of unintentional loosening of Clamp Nut on Earthing Terminal Bolts, the risk of Operator getting a shock (*incase of Insulation leakage*) is much higher than a Submersible system wherein the natural water farthing diverts the shock away from operator. For eg, in India, LV Submersible motors are prevalent, but in Europe MV submersible motors are in use since decades and that too WITHOUT an Earthing cable ..! In fact the IS 8034 of agricultural bore hole submersible motors neither mandates nor recommends an Earth core at all (*which in itself is a proof that any potential leakages from windings phases are better grounded by water to earth & use of earthing cables brought out to Ground level earth pits are not as effective as naturally available water earthing*).

The elaborate protection systems as outlined above do not on any way mean to deter the reader from use of MV submerged motors which are at least as safe (if not higher) as compared to Dry Installed MV motors.