Guide to Specifying a Powered Manipulator for Operation in Hazardous Environments – 15510

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ABSTRACT

Manipulators have been used extensively to perform remote nuclear operations, handle hazardous materials and perform decommissioning activities. As payload and reach requirements increase, manually powered tooling options are often underpowered, or too delicate to perform. When this occurs powered manipulators are often used to meet the need. Powered manipulator types commonly used are electromechanically powered and hydraulically powered manipulators. A number of factors will need to be weighed in order to determine the type of manipulator that best meets the needs of the application. While there is not a single manipulator type that is best suited for all applications each type has its own strengths and weaknesses. The challenge to the site operator is to determine the most effective solution for the job at hand. Operating envelope, installation methods, control system, payload, radiation levels and failure modes are some of the most important requirements to consider. Regardless of the manipulator type chosen the most economical solution is often a customized pre-engineered solution. Existing, proven designs can often be modified slightly to meet the unique needs of a project. Often times it is not possible to meet requirements with a pre-engineered solution and a custom solution must be created. Even with a custom design standard design elements can often be used to decrease cost, increase reliability and improve performance.

INTRODUCTION

When the need arises to utilize a powered manipulator for remote handling a specification must be produced to communicate the needs to the supplier of the equipment so that the task can be completed safely and successfully. In order to create a specification all environmental, radiological, lifecycle and operating parameters must be accounted for. Working with a custom equipment supplier from the start of a project can ensure that all requirements are met and if possible existing technologies can be leveraged to the maximum extent possible thereby reducing total system cost, lead time and improving overall reliability. Included is an overview of pre-engineered hydraulic and electromechanical solutions, the ModuMan 100, ModuMan PRM, A1000 and the TELBOT manipulator systems.

DESCRIPTION

Both hydraulic and electromechanical manipulators can be created to meet high payload requirements however each type has strengths and weaknesses. Hydraulic manipulators often have higher power densities because pressure can often be converted into final element motion without additional gearing or mechanical elements. Additionally the form factor of a hydraulically powered joint is often more streamlined than a comparably sized electro mechanical joint. This benefit of hydraulically powered manipulators can be seen in both the

ModuMan100 and the ModuMan PRM as both can be installed in standard master slave manipulator ports.

Electromechanical manipulators often have better accuracy, speed and repeatability when compared with hydraulic manipulators however advanced control systems can help minimize the loss in hydraulic manipulators. Applications with restrictive maintenance requirements, higher precision requirements, or more forgiving access are often solved with electromechanical manipulators.

Radiation Tolerance

Both electromechanical and hydraulic manipulators can be designed for use within high radiation environments. All materials including electronics, insulation, electrical components, hoses, seals and bearing materials must be tolerant of radiation levels and most integrated circuits must be avoided. In addition to ionizing radiation, ease of decontamination must be designed into the manipulator. In some cases a boot or shroud can be installed over the actuator to provide a second barrier to prevent or reduce contamination.

Failure Modes

In many instances failure modes of the manipulator and the subsequent recovery of the manipulator are key factors in the type of manipulator selected. Electromechanical systems have little or no risk of introducing fluids into the operating environment. In most applications the manipulator is expected to remain in place if a failure occurs or if power to the device is lost. In electromechanical actuators this can be accomplished through the use of gearing or integral braking. In this case, alternative recovery plans and tooling must be developed to allow for retrieval of the unit into a maintenance area. The Telbot is a special design that allows opening the brakes and it becomes limp.

Likewise with hydraulic manipulators hydraulic fluid can leak from fittings if they loosen over time or in the case of rare catastrophic failure a larger volume can be released quickly. For hydraulic systems counterbalance valves are used to prevent unwanted motion in case of pressure loss. In case of a failure the manipulator will likely need to be removed from the installation in order to be repaired. Hydraulic manipulators generally have all valves located outside the environment. This allows the pressure stored within the manipulator to be relieved and the manipulator to become limp. Once limp the manipulator can be retrieved by simply pulling the unit through the wall or penetration.

Tooling

Both electromechanical and hydraulic manipulators can be outfitted with a variety of tools. Tools can be held by the gripper using a T-handle or by a tool changer that includes pass-through for hydraulics, pneumatics and electrical connections. Some examples of commonly used tooling are:

- Grippers
- Shears

- Torches, plasma or water jet
- Grinders
- Chisels
- Reciprocating/oscillating saws
- Circular saws
- Adhesive/chemical delivery systems

Services for tooling can be routed within the manipulator or from an umbilical located outside the manipulator.

Control Systems

Both electromechanical and hydraulic manipulators can be supplied with basic to advanced control systems. Advanced control systems can greatly increase productivity of the manipulator and provide additional safety and diagnostic capability. A typical six axis HMI is shown below in Figure 1.

Figure 1 - Typical Human Machine Interface

Joint by joint movement is a scheme in which the operator manually coordinates all of the movements of the manipulator through the use of a set of two three axis joysticks. This mode of operation is often used if a more advanced control system is not specified or in particular instances where the configuration of the joint must be changed to avoid other obstacles within the environment.

Advanced control systems use a computer system to coordinate the movement of each joint to produce the desired motion from the manipulator end effector. In order to accomplish this each joint must provide position feedback so that the control system can calculate the position of the manipulator within the environment. With an advanced control system the gripper or tool of the manipulator can be driven either in world mode or tool mode. In world mode the operator directs the movement of the manipulator in a stationary Cartesian coordinate system which is useful for moving items around the environment. In tool mode the operator directs the gripper or tool of the manipulator using a coordinate system that moves with the tool. Tool mode is useful in size reduction efforts, tool change efforts and detailed tasks such as completing service connections.

Additionally, control systems can be easily modified to prevent collisions and provide force feedback to the operator. Collision avoidance systems prevent contact with cell walls or other objects within the environment to prevent damage to both the manipulator and objects within the environment. Force feedback features can prevent the manipulator from damaging items or itself in the process of completing needed tasks.

Customizable Pre-engineered Manipulator Examples

Below is a general overview of four commercially available manipulators that can be easily customized to meet site specific needs. Again there is not a single type of manipulator that is best suited for all tasks and the best solution may be a custom manipulator that meets the specific needs of the task at hand.

The ModuMan 100 shown in Figure 2 is a rigorously tested 6 degree of freedom hydraulic manipulator that offers a 100kg (220 lb) payload capability with a 2.54 meter (100 inch) reach. The manipulator is designed to be deployed through a standard MSM port however other custom mountings can be used to increase the operating range of the manipulator. All valves are located on the clean side of the penetration with each joint having position feedback through the use of radiation tolerant resolvers.

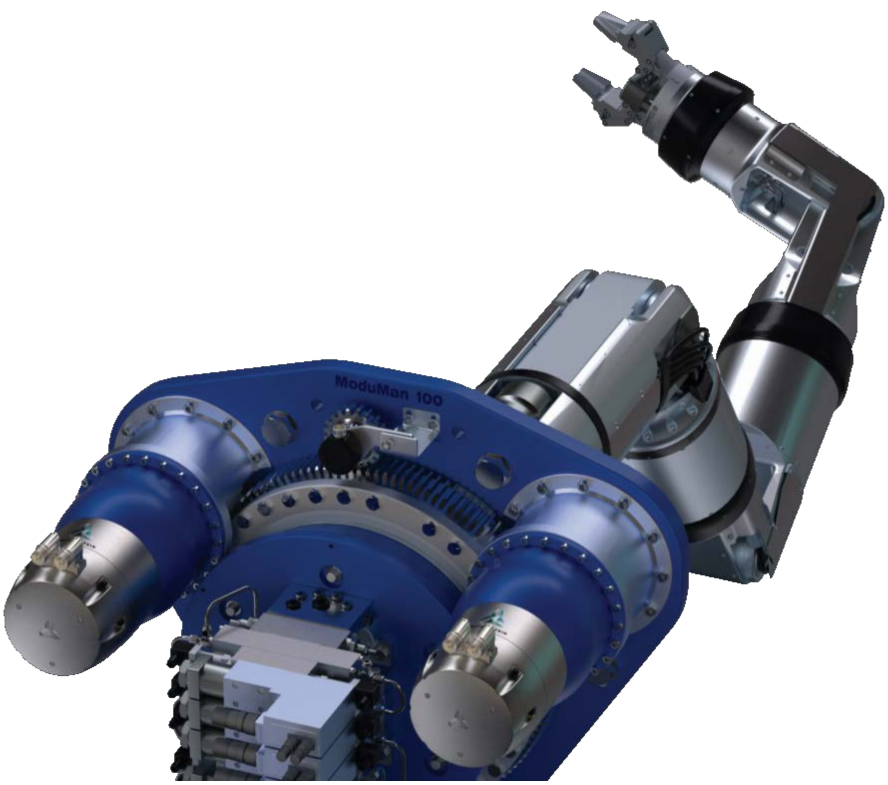

Figure 2 - ModuMan 100 Hydraulic Manipulator

The ModuMan PRM shown in Figure 3 is another highly reliable hydraulically powered manipulator. This manipulator has 7 joints with 6 degrees of freedom a 50 kg (100 lb) payload capacity with a 4.2 meter (165 inch) reach. Similar to the ModuMan 100 resolvers are used for position feedback and all valves and control equipment is located in the out cell area. The unique dual elbow joint of the ModuMan PRM allows for a full ±180° of motion making this manipulator incredibly dexterous.

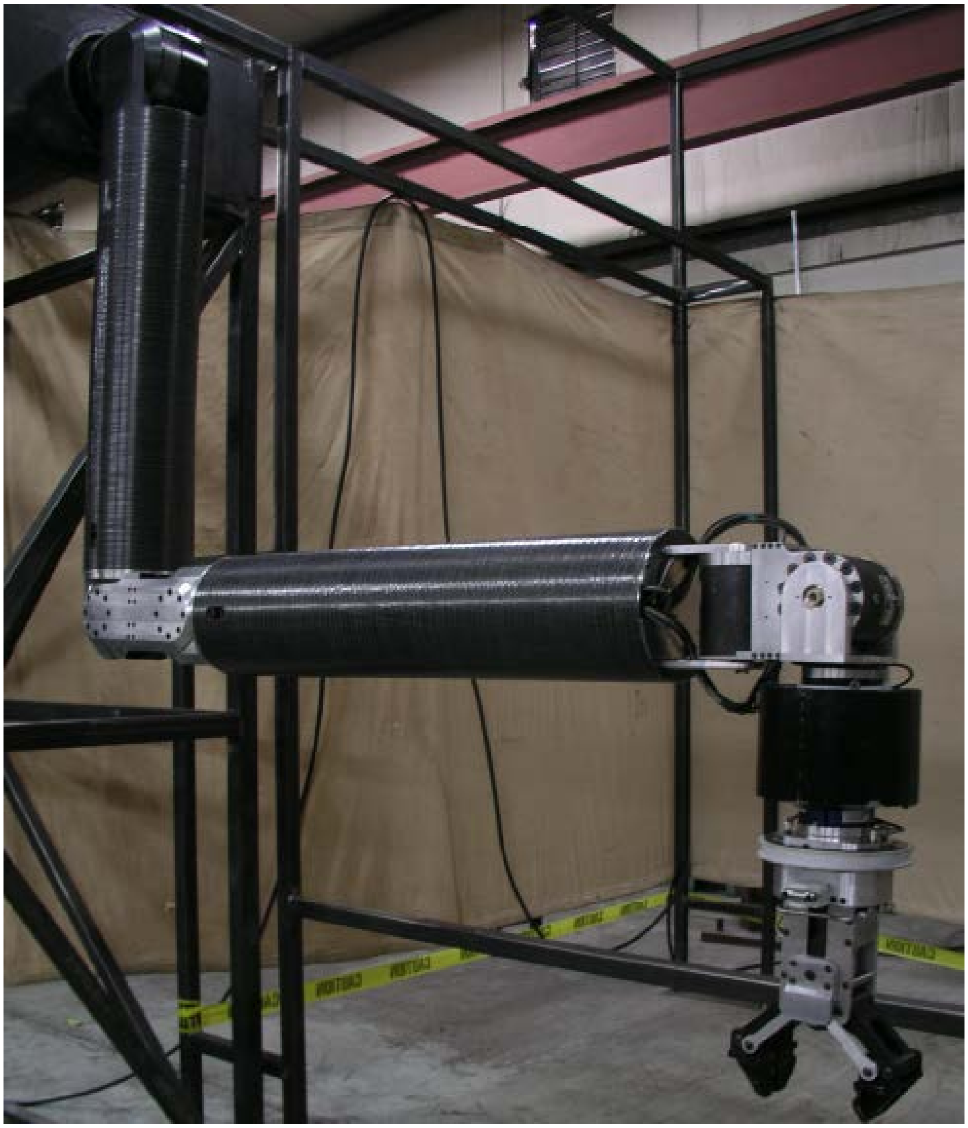

Figure 3 – ModuMan PRM Hydraulic Manipulator

The A1000 manipulator shown below in Figure 4 is typically a gantry deployed electromechanical manipulator with telescoping mast and 6 degrees of freedom. Using the gantry system it has a very wide working envelope. In this case the manipulator is capable of a 50 to 500 kg (110 to 1100 lb) payload depending on reach. There is no external wiring along the mast and the manipulator arm and most joints are capable of continuous rotation.

Figure 4 - A1000 Electromechanical Manipulator

The TELBOT, see Figure 5 below, is a larger electromechanical manipulator that uses concentric tubes and bevel gears to drive all joints from the drive unit. The drive unit can be located in the out cell area and contains also the resolvers. The offset in the joints offers continuous rotation but causes bigger penetrations. This manipulator can easily be configured with various joint types and lengths. Overall payload is reliant on reach and can vary between 5 to 150 kg (11 to 330 lb). This manipulator is capable of fast and repeatable precise movements. The entire assembly is sealed and can be operated under water or in wet or hazardous environments. The TELBOT can utilize the Masterarm, a force feedback control system that duplicates each joint of the manipulator in the out cell area for intuitive control.

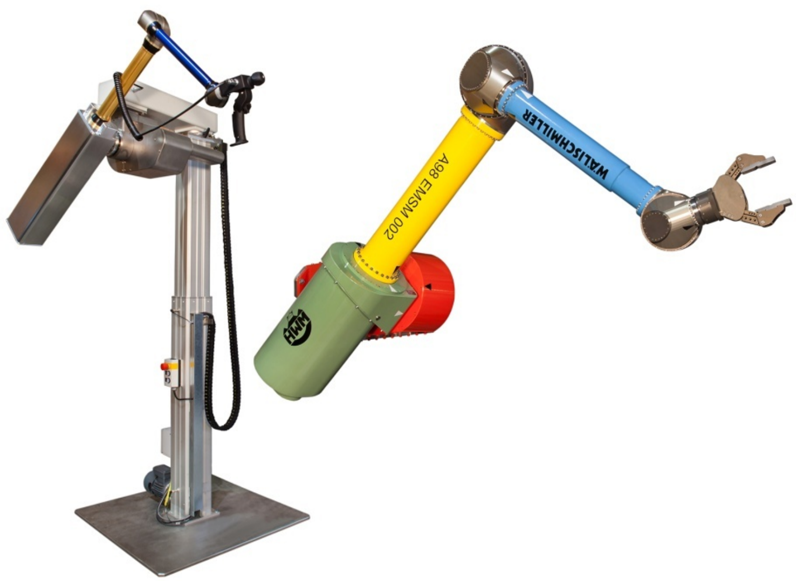

Figure 5 - TELBOT Electromechanical Manipulator

The four examples of both electromechanical and hydraulic manipulators above show typical attributes of each type. Each example above reflects some of the most generalized manipulators available with each being capable of being customized to be deployed from mobile crawlers, cranes, booms, or gantries.

CONCLUSION

Both electromechanical and hydraulic manipulators have a place in the nuclear environment. The brute force of hydraulics and the elegant accuracy of electromechanical manipulators offer a full suite of models that can be used to meet almost any need. When a commercially available manipulator is not available a complete and reliable custom solution can be engineered to meet high load, long reach, tough environments or difficult access. By carefully taking inventory of requirements and any operational flexibility it is likely that a customizable pre-engineered solution can be modified to quickly meet specific needs. This will improve the performance by reducing cost, and lead time while improving overall mission success and reliability.