Metal Detection in Hazard Area by using Automated Electrical Vehicle

Mahmoud M.Samy and T. M.EL-Saied*
Benha higher institute of technology, Egypt.
*E-mail: tamer18@hotmail.com

Abstract: This paper gives design details of electrical automated vehicle used in hazard area to detected underground buried metal.

Practical control techniques are used by new AB Micrologix1400 to control vehicle motion, direction, detection and recognition of the metal area.

Metal detector sensor attached to the bottom of electrical car to detect metal in the range of 25cm, color tank and electrical valve used to highlight/spot the detected area, wireless Ethernet communication used to update the program direction and car status remotely in the range of 150m.

Small car model had been built with DC motor to control forward and reverse direction and stepper motor installed in the front wheel to accurately change the car direction.

Movement of the car is preprogrammed and stored in the PLC memory to scan and detect metal in area of 25mX25m automatically.

Also user can change the motion from automatic to manual override in special cases when Barriers found in the scanned area.

Keywords: PLC, electrical vehicle, metal detector, battery charger, Allen Bradley

1. APPLICATION:

PLC unit and sensor used to control the movement of the metal detector vehicle with different methods of land scanning to detect the mine.

1.1. Vehicle Body:

The body of the vehicle designed from two parts, first is the chasses which used to fix the bearing used to carry the back shaft which contain the rings installed on the motor shaft by the tensioned belt which cause the movement, Also used to fix the front mechanism which contains the gear of the stepper motor, this mechanism designed to achieve 2.5^o degree/teeth-movement to change the direction of movement.

Fig 1 The DC Motor and Stepper Motor

Fig 2The chasses of the vehicle

The second part is the cover used to protect the components.

Fig 3 The cover

1.2. Movement of Vehicle:

The traffic force will be given through the back wheels by the DC motor which will get the signal from the PLC and H-Bridge for moving forward and reverse, and the direction control by the front wheels using the stepper motor for steering clock wise (CW) and counter clock wise (CCW).

DC motor was used because of the availability of the battery and also to give the force/torque required for movement of the vehicle, stepper motor used to give accurate angle and high torque.

Two mode of operation are used to scan the area, first is automatic scan mode which scan the area based on previously saved chart on the memory of the PLC, second is manual scan mode which control the movement by remote control SCADA communicating with the PLC using wireless Ethernet.

In case of detecting metal by the Proximity sensor the vehicle will stop, then the spray valve will open to spot the area by red color from the tank installed in front area in the vehicle.

1.2.1. Automatic scan mode:

In the following fig. vehicle will start scan from lift bottom side at the start point and follow the track to reach the top side. Vehicle will change the direction at the beginning and end of each track of the array.

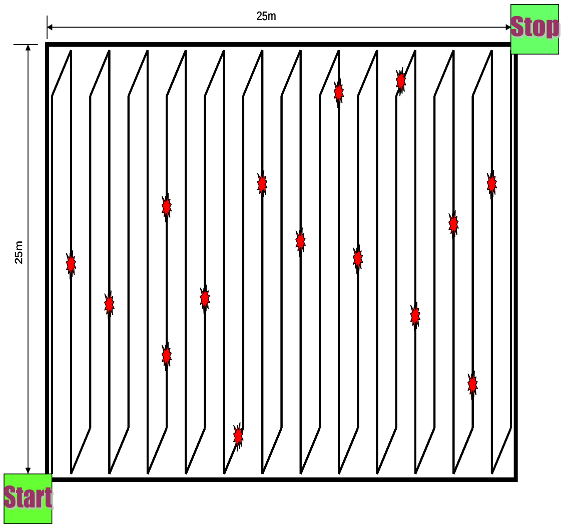

Fig 4 The Automatic scan mode

1.2.2. Manually scan:

We are using the Ethernet port in the PLC and wireless access point remotely control movement/direction and monitoring of the vehicle position using SCADA.

2. Mechanical model of the vehicle:

Calculation of tractive effort.

Consider a vehicle of mass m, proceeding at a velocity v, up a slope of angle ψ, as Figure 1. The force propelling the vehicle forward, the tractive effort, has to accomplish the following:

- Overcome the rolling resistance;
- Overcome the aerodynamic drag;
- Provide the force needed to overcome the component of the vehicle’s weight acting
- Down the slope.
- Accelerate the vehicle, if the velocity is not constant.

We will consider each of these in turn.

2.1. Rolling resistance force

The rolling resistance is primarily due to the friction of the vehicle tyre on the road.

The equation is:

$$F_{rr}=\mu_{rr}.mg \qquad (1)$$

where μrr is the coefficient of rolling resistance

Typical values of μrr are 0.015 for a radial ply tyre, down to about 0.005 for tyres developed especially for electric vehicles.

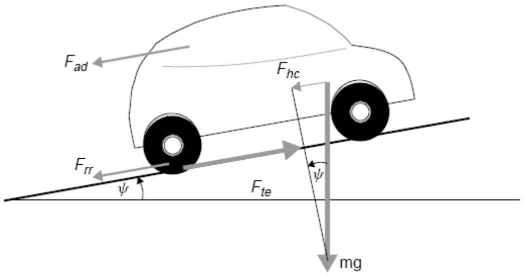

Fig 5 The forces acting on a vehicle moving along a slope

2.2. Aerodynamic drag

This part of the force is due to the friction of the vehicle body moving through the air.

The formula for this component is:

$$F_{ad}=\frac{1}{2}\rho A C_d v^2 \qquad (2)$$

where ρ is the density of the air, A is the frontal area, and v is the velocity. Cd is a constant called the drag coefficient.

Cd figures of around 0.7 are more typical in such cases.

Provided that SI units are used (m2 for A, m.s−1 for v) then the value of Fad will be given in Newtons.

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2.3. Hill climbing force

The force needed to drive the vehicle up a slope is the most straightforward to find.

$$F_{hc}=mg\sin(\psi) \qquad (3)$$

2.4. Acceleration force

If the velocity of the vehicle is changing, then clearly a force will need to be applied in addition to the forces shown in Figure 1.

the well-known equation derived from Newton’s second law,

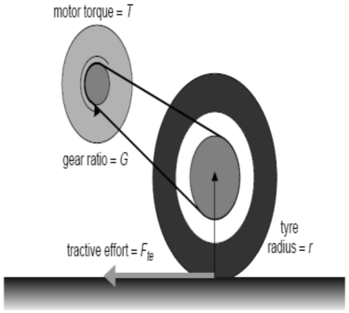

Fig 6 A simple arrangement for connecting a motor to a drive wheel

$$F_{la}=ma \qquad (4)$$

Referring to Figure 6, clearly the axle torque = Fter, where r is the radius of the tyre, and Fte is the tractive effort delivered by the powertrain. If G is the gear ratio of the system connecting the motor to the axle, and T is the motor torque, then we can say that:

$$T = \frac{F_{te} r}{G} \qquad (5)$$

and $$F_{te} = \frac{G}{r} T$$

$$\text{axle angular speed} = \frac{v}{r} \ \text{rad.s}^{-1}$$

So motor angular speed

$$\omega = G \frac{v}{r} \ \text{rad.s}^{-1}$$

$$F_{\omega a} = \frac{G}{r} I G \frac{a}{r}$$

$$F_{\omega a} = I \frac{G^2}{r^2} a$$

the equation by incorporating the gear system efficiency ηg. The force required will be slightly larger, so equation can be refined to:

$$F_{\omega a} = I \frac{G^2}{\eta_g r^2} a \qquad (6)$$

Typical values for the constants here are 40 for G/r and 0.025 kg.m2 for the moment of inertia.

2.5. Total tractive effort

The total tractive effort is the sum of all these forces:

$$F_{te} = F_{rr} + F_{ad} + F_{hc} + F_{la} + F_{\omega a} \qquad (7)$$

We should note that Fla and Fωa will be negative if the vehicle is slowing down, and that Fhc will be negative if it is going downhill.

3. Semiconductor H-Bridges:

Control of motor took place by using BJT transistors or Field Effect Transistors (FETs). Diodes are used across transistors to act as a freewheel.

4. Stepper Motor Driver Layout:

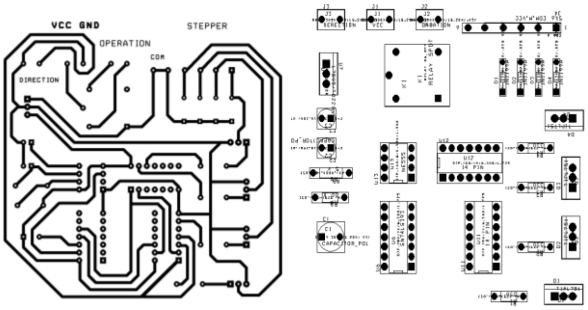

Fig 7 The Stepper Motor Driver Layout

5. Programmable Logic Control (PLC) Micrologix 1400:

Fig 8 Micrologix 1400 PLC unit

5.1. General Specification:

The PLC have 32 digital I/O with or without analog and have many type from the communication ports -(2) RS232 ports and (1) Eth port, 8 preconfigured Web pages, Remote control via Web (access through password), Diagnostic information (I/O status, communication status, alarms, faults...) and Access to data table also to modify parameters (integer, long integer, float, bit).

5.2. Ethernet/IP - CIP:

Will support two new Ethernet protocol Modbus TCP and DNP3

Supports the following Ethernet protocols:

1. SMTP - Simple Mail Transport Protocol to send e-mail
2. HTTP - Hyper Text Transfer Protocol for web server

6. Inductive Proximity Sensors

6.1. Theory of Operation

In this section we will look at inductive proximity sensors, and how they detect the presence of an object without coming into physical contact with it. Inductive proximity sensors are available in a variety of sizes and configurations to meet varying applications. Specific sensors will be covered in more detailed in the following section

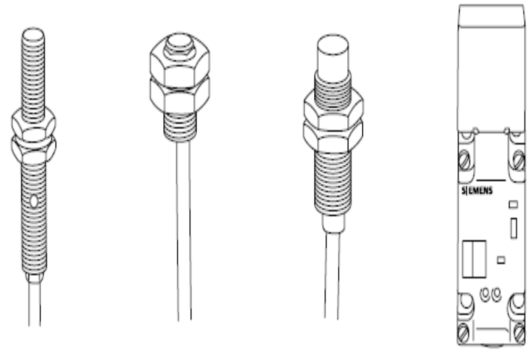

Fig 9 The samples of Inductive Proximity Sensors

6.2. Electromagnetic Coil and Metal Target

The sensor incorporates an electromagnetic coil which is used to detect the presence of a conductive metal object. The sensor will ignore the presence of an object if it is not metal.

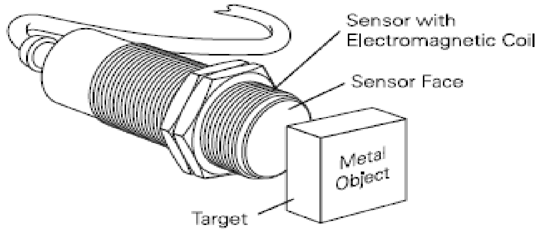

Fig 10 The detect of presence a metal

6.3. ECKO

Inductive proximity sensors are operated using an Eddy Current Killed Oscillator (ECKO) principle. This type of sensor consists of four elements: coil, oscillator, trigger circuit, and an output. The oscillator is an inductive capacitive tuned circuit that creates a radio frequency. The electromagnetic field produced by the oscillator is emitted from the coil away from the face of the sensor. The circuit has just enough feedback from the field to keep the oscillator going.

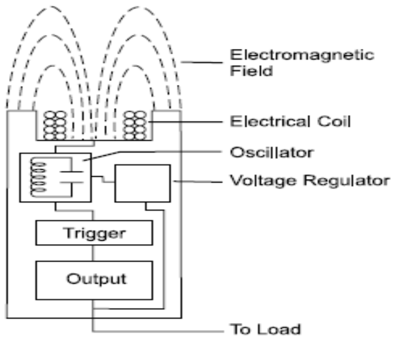

Fig 11 The ECKO sensor

When a metal target enters the field, eddy currents circulate within the target. This causes a load on the sensor, decreasing the amplitude of the electromagnetic field. As the target approaches the sensor the eddy currents increase, increasing the load on the oscillator and further decreasing the amplitude of the field. The trigger circuit monitors the oscillator's amplitude and at a predetermined level switches the output state of the sensor from its normal condition (on or off). As the target moves away from the sensor, the oscillator's amplitude increases. At a predetermined level the trigger switches the output state of the sensor back to its normal condition (on or off).

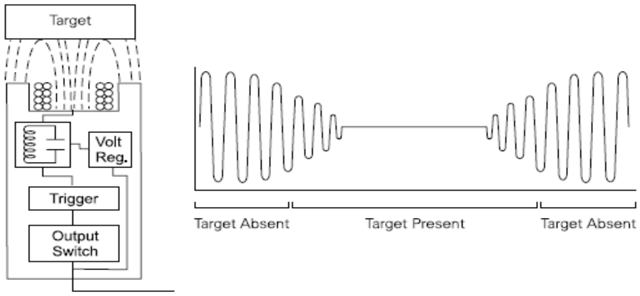

Fig 12 The detect of presence a metal

ACKNOWLEDGMENT

The preferred spelling of the word "acknowledgment" in America is without an "e" after the "g." Try to avoid the stilted expression, "One of us (R. B. G.) thanks …" Instead, try "R.B.G. thanks …" Put sponsor acknowledgments in the unnumbered footnote on the first page.

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