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Economics around Technical Specifications of Power and Control Cables

Amit Sinha[1], Pankaj Kumar[2], Mili Das Mohapatra[3]

[1]Electrical, Fluor Daniel Pvt Ltd, Gurgaon, Haryana, India

[2]Electrical, Fluor Daniel Pvt Ltd, Gurgaon, Haryana, India

[3]Electrical, Fluor Daniel Pvt Ltd, Gurgaon, Haryana, India

ABSTRACT: The paper is an initiative towards creating awareness among the engineering consulting professionals, specially involved in large industrial projects, about the cost of the power and control cables and importance of knowing the differential price of cables based on their various technical features. With the insight of the commercial attributes of technical parameters of cables & further their differential cost, a logical commercial quantification of cables can be achieved. Further to this, prudent and informed decisions can be taken on the magnitude and viability of cables optimization on any project or proposal. The paper also attempts to discuss some key technical features of cables and their corresponding price addition in percentage of the base price. The paper in a way aspires to create a culture among the technical professionals to weigh in the commercial aspect of any technical parameter while implementing them in the design of any project.

KEYWORDS:MTO- Material take-off, LSZH – Low smoke, zero halogen, FR – Flame retardant, FS- Fire resistant, XLPE- Cross linked polyethene, PVC- Poly Vinyl chloride, MV- Medium voltage 3.3kV or above, LV- Low voltage 400V or below, OEM- Original Equipment manufacturer

I.INTRODUCTION

Cables and their accessories have a critical share in the budget of electrical installation in any industrial project. Typically, in an oil and gas, and large petrochemical project set up, they can be as high as up to **20%** of the total cost of electrical equipment and installation. Moreover, the cable laying and termination cost levied by the construction sub-contractor is hugely dependent on the cable sizes furnished to the min the MTO. At times, the cable laying infrastructure cost and correspondingly the service charge quoted by site contractors to lay and install them are higher or even up to double of the cable cost. This range varies with the location of the project and cost of site-manpower in that country. Further, the parameters like insulation, type of armoring, fire protection properties, conductor material, core quantity, shielding, to name a few, have a considerable bearing on the cable's price. Therefore, it is of paramount importance that cable type selection, and its sizing are done very prudently during the proposal or detailed engineering of any large project, as they become the originating point of the overall cost build-up of the cabling infrastructure.

In this paper, price variance of the cables based on certain comparative parameters like PVC vs XLPE insulation, copper vs aluminum conductor, armored vs unarmored, cable size vs next higher size, power cable vs control cable in LV system, paired control cable vs core-control cable, FRLS vs FR vs LSZH vs fire resistant and standard cable drums vs non-standard cable drums are elaborated. Numerous price list and historical quotes by cable manufacturers along with thepast project cost data have been utilized to demonstrate these price variations, and this is indicated in percentage, to make it little generic and applicable across any project in any country.

II.PVC VS XLPE INSULATION

In mid-sixties, while PVC insulation was prevailing on inner as well as outer sheaths, the XLPE insulation on the inner sheath was introduced. The outer sheath insulation invariably is still PVC these days. The XLPE insulation on inner sheath brought in numerous technical benefits but came with a price premium. The technical benefits of XLPE also translated into some commercial advantages vis-à-vis the PVC insulated cables, but this again could be realised only through the price premium. The commercial advantages of XLPE insulation are as below

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1. Service life is 40 to 60 years, higher than PVC cables
2. Higher current rating hence one size lower cable can be utilized
3. Lower laying and lower installation cost as XLPE have smaller diameter, hence smaller bending radius

Owing toso many advantages, the consumption and therefore production of XLPE cables for industrial use rose so much that during the present days, owing to the factor of economy of scale, either PVC and XLPE insulated cables are equally priced or PVC insulated cables are **5-8%** more expensive than XLPE insulated cables. his percentage is lower for copper conductor cables as compared with the aluminium conductor cables, as the former already has a higher absolute price. Also, as cable sizes go higher, this percentage difference in the price gets slimmer between XLPE and PVC.

Apart from the above, the Heat resistant PVC cables, which is an advanced version of PVC cables, known as HR-PVC, has an exclusive feature of withstanding continuous temperature of 100 or 120 or 150 degrees Celsius, which is higher than the usual PVC, i.e., 70 degrees Celsius. The HR-PVC are therefore **7-10%** further higher priced than XLPE. And if both the inner as well as outer sheaths are HR PVC, for each there is **5%** further increase in the price.

III.COPPER VS ALUMINIUM CONDUCTOR

During the world war-II, owing to increased demands from the arms industry, there became a shortage of copper leading to a fast appreciation in the global copper prices. Aluminum as a conductor of electricity then became a viable alternative as aluminum was and still is one of the most abundant metals on the planet and has an excellent thermal and electrical conductivity.

In the present times, as per London metal exchange, which is the world center for the trading of industrial metals, the price of copper is 3-4 times more than that of the aluminum. When these metals form a part of the industrial cables, in the smaller cable size range, from 1.5 sq mm to 50 sq mm, considering indigenous context, copper cables are priced higher than the aluminum cable varying in the range of 2 to 6 times. However, for higher sizes above 70 sq mm, the copper cables price is comfortably 6 to 8 times more than the aluminum. For large industrial projects, as the quantum of cables procured is very high, ranging between 100km to 1000km or beyond in any project, the cable manufactures can provide additional discount on copper cables, and therefore with the perspective of large industrial projects, copper cables price can be considered as 3 to 4 times that of aluminum cables.

Below Table 3.1 is a compilation of price variance of aluminum and copper cable for 1100V grade XLPE insulated un-armored cable. This has been taken as an average of multiple cable manufactures price list. It shows the copper cable price for higher sized cables ranging from 120 sq mm to 630 sq mm is 7 to 8 times than that of aluminum.

							Drum size	No of times
Voltage grad	Insulati	Copper/Aluminiu	Core si	moured/Unarm	FRLS	INR per metre	500	No of times
1100V	XLPE	Aluminum	120	Unarmoured	Yes	200	100000	
1100V	XLPE	Aluminum	150	Unarmoured	Yes	250	125000	
1100V	XLPE	Aluminum	240	Unarmoured	Yes	375	187500	
1100V	XLPE	Aluminum	300	Unarmoured	Yes	460	230000	
1100V	XLPE	Aluminum	400	Unarmoured	Yes	600	300000	
1100V	XLPE	Aluminum	630	Unarmoured	Yes	860	430000	
1100V	XLPE	Copper	120	Unarmoured	Yes	1400	700000	7.00
1100V	XLPE	Copper	150	Unarmoured	Yes	1750	875000	7.00
1100V	XLPE	Copper	240	Unarmoured	Yes	2800	1400000	7.47
1100V	XLPE	Copper	300	Unarmoured	Yes	3500	1750000	7.61
1100V	XLPE	Copper	400	Unarmoured	Yes	4600	2300000	7.67
1100V	XLPE	Copper	630	Unarmoured	Yes	7250	3625000	8.43

Table 3.1

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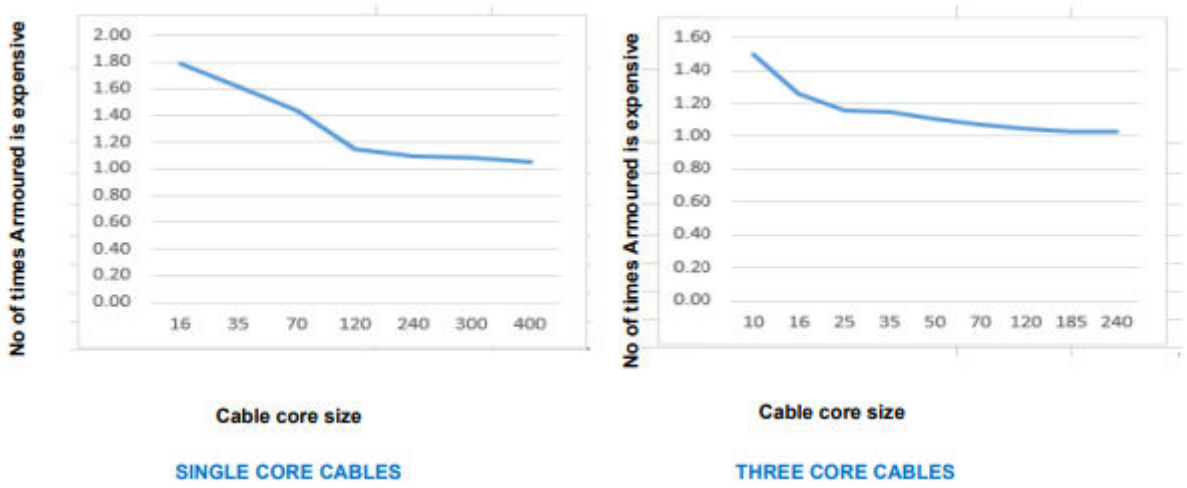
IV. ARMOURED VS UNARMOURED CABLE

It is very well known to all that, armoured cables are costlier than unarmoured cables. But the percentage or magnitude by which they are costlier and how does this percentage vary in what range of cables size is a matter of some importance. These data can assist the designer and engineer to plan and envisage unarmoured cables in some specific areas of the plant, where the contract or project specification allows to do so. Characteristically, unarmoured cables are more prone to external injuries and may need at times conduits to compensate for the safety, that does add to the cost. But where they can be laid safely in the trays, there it leads to lesser bending radius and therefore some savings in the cable laying infrastructure. Hence, knowledge of a comparative price variance between the armoured and unarmoured cables can assist in taking better decisions.

The following graph shows that in single core cables, up to 95 sq mm, the armoured cable is **20% to 80%** more expensive. Beyond that, i.e., from 120 sq mm single core cable size to higher, armoured, and unarmoured are less than 10% different in price. On the other hand, in three-core cables, it is only up to 16 sq mm, the difference in cost is **25% to 50%**. Beyond 25 sq mm, the cost difference lies within **10%.** Note that at very higher sizes, sat at 400 sq mm, the cost difference almost vanishes. The knowledge of these price variances can prove helpful during design &planning.

Further to this, armoured cables are also of three broad categories, the price of each are different. They are wire armoured, strip or tape armoured, and the round wire armoured. While the strip or tape armoured is more expensive than the wire armoured, the round wire armoured is the costliest, and is up to **25 %**higher than the wire armoured. Armour can also be of different materials such as aluminium, steel and copper, and their price varies in the increasing order from aluminium to steel to copper.



V.CABLE SIZE VS ITS NEXT HIGHER CABLE SIZE

Cable size selection for all the loads in any project is an exhaustive task as it encompasses electrical load at every nook and corner of the project. In quite a few occasions, to mitigate the cumbersome job, cable size selection for variety of loads in large projects isstandardised to some extentas that helps in procurement and cable management at site. However, while doing this, attention must be paid to the additional expense that gets continuously built in along, when a cable size is selected one step or may be two steps higher than the technically required size. Cumulatively, these miniscule increment in price eventually result in a considerable overrun from the estimated cost of cable procurement and installation.

In lower cable sizes with copper conductor, i.e., up to 70 sq mm, selection of one step higher cable size attracts **35% to 45%** increase in the cable cost. In higher cable sizes in copper conductor and in across all the cable size range in aluminium conductor, one step higher cable size attracts **20-25%** increase in the cable cost. It is also noteworthy that the installation infrastructure and installation service cost is wholly incumbent on this metric only. Therefore, the overall cost of cable installation also balloons up further. To elaborate, the lugs, glands, tray, conduits, sleeves, trench, supports and everything associated with cable gets costlier as the cable size increases.

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VI.EARTHED AND UNEARTHED MV CABLE

In Medium Voltage systems, earthed and unearthed cable requirement is dependent upon the type of system earthing ,i.e.,g rounded, or ungrounded system. In MV system, transformers and generators that are now available have very high capacity and therefore higher fault levels. So, if there is an earth fault, a heavy current flow into the fault, which leads to the damage of the generators and transformers. At this voltage level, the exposure of operators or civilians to the equipment is meagre, hence importance of equipment safety is more pronounced. Hence, for this large capital-intensive equipment safety, to reduce the fault current, the star point is connected to the earth through a resistance. In case of an earth fault in one phase, the voltage of the faulty phase with respect to the earth appears across the resistance. Due to this, the voltage of the remaining two healthy phases with respect to the earth rises by 1.7 times. If the insulation system is not designed to sustain these increased voltages, they are likely to develop further earth faults.

Unearthed cable is therefore used in ungrounded/ high resistance earthed distribution system, as this offers higher insulation than earthed cable. In an unearthed cable, the insulation level of the conductor to the Armor is equal to the insulation level of conductor to conductor. This is because, if an earth fault occurs in the ungrounded system, the voltage between the healthy phases and the ground will be equal to phase-to-phase voltage. In the three phase earthed systems, phase to earth voltage is 1.732 times less than phase to phase voltage. Thus, the voltage stress on the cable to Armor is 1.732 times less than the voltage stress between conductor to conductor.
In view of the above, compared with the earthed cable, the unearthed cable needs higher insulation levels. The prime difference between earthed and unearthed cable arises in the voltage grade (Uo/U), which is shown below**Table 6.1** :

Earthed System	Unearthed System
1.9/3.3 kV, 3.8/6.6 kV, 6.35/11 kV, 12.7/22 kV and 19/33 kV	3.3/3.3 kV and 11/11 kV

From the above, it isestablished that an unearthed cable will demand extra price over an earthed cable. This difference is in the range of only **4% to 7%**, and that also up to the cable size of 240sq mm. While going to higher cable size, the difference almost vanishes or stays near **1%-2%.**
The above facts also translate that 6.35/11kV earthed grade cable for an earthed system can also be used in the place of 6.6/6.6 kV unearthed grade cablefor an unearthed system
.

VII. FRLS VS LSZH VS FIRE RESISTANT/ FIRE SURVIVAL CABLES

FRLS is an abbreviation of flame retardant, low smoke. Many a times it is misunderstood as flame or fire resistant, low smoke, which is incorrect. Flame or Fire resistant (FR) is a superior property and it comes with a considerable additional price and superior construction. Fire resistant (FR) cable is often called Fire survival (FS) cable, and they are one and the same thing.

The word retardant implies that the fire in the cable gets extinguished immediately on removal of source. The word resistant implies that there is a specific non-flammable layer around the conductors such that even if the separating insulation gets burnt, conductors will not get short circuited and the integrity of electrical continuity will be maintained, for the stipulated number of hours, as prescribed by the manufacturer. This justifies the extra price this feature should claim.

FRLS stands for flame retardant, low smoke, where low smoke is a property achieved by limiting the halogen content on the inner sheath and outer sheath material, that

result in limiting the density of smoke and therefore causes limited corrosion of equipment and low suffocation of humans who are trapped. Lower the halogen content, better the cable is for handling the fire. The loading of this feature attracts anoverall cable price increment by**5-10%** for inner sheath and by **5-7.5%** for the outer sheath.

LSZH stands for low smoke, zero halogen, that implies the content of chemical called HCl in the insulation is less than 0.5%. This feature ensures that the formation of toxin dioxins and furanethat causes acidic fumes are considerably reduced, and therefore become very suitable and apt for usage in tunnels, hospitals, cinema halls, control rooms, office buildings, etc. It also has high resistance against grease, oil, and emulsion and thereby suitable for stock removing machine tools. The loading of this feature attracts a considerable increase in price of the cable. The below Table 7.1 indicates the same.

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Cable Type (Sq.mm)	LSZH	
	Inner sheath	Outer sheath
	Power (Al)	
Up to 16	15%	20%
25 to 50	12.5%	15%
70 & Abv	15%	12.5%
	Power single core (Al)	
Up to 16	25%	
25 to 70	20%	
95 & Abv	17.5%	

Table 7.1

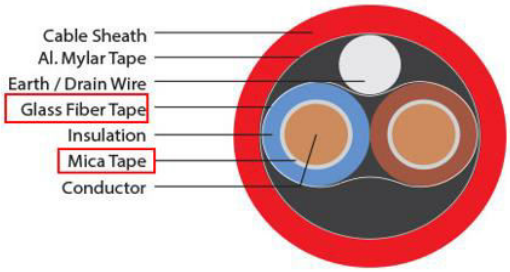

Figure 7.1

Fire resistant or Fire survival cables are designed as described earlier and as depicted in the above image. These are apt for vital and emergency services. Their individual conductors are wrapped with a layer of fire resisting mica/glass tape/silicone which does not let the conductors to get short circuited. The exhibit same performance even under fire with spray or mechanical shock situation.Fire resistant cables have in general all the basic properties of FRLS cables, but owing to the below additional features, their price gets stepped up.

1. Copper is preferable to aluminium, as copper melting point is 1085 degrees Celsius and aluminium melting point is 660 degrees Celsius. IS:16246 & BS:7846 recommend only copper conductors for fire resistant application. In general, up to 50 sq mm, Copper is strongly advisable instead of aluminium for enhanced mechanical strength needed against fire. Inclusion of this leads to **300-400% rise** in cable price.
2. LS-ZH coating gets included to ensure low smoke & less toxic gases and safe evacuation:The inner sheath bumps up the price by **7.5 %**&the outer sheath kicks it further up by **7.5%.**
3. Round wired Armor gets included for higher mechanical strength against falling objects during fire, which is costlier than taped/ strip wired armoured by **25%.**
4. Mica tape on each conductor increase the price by prevalent rates of mica.
5. Additional ceramic silicone technology that becomes glass like insulator to protect cable conductor against attack by water during firefighting. This further increases the price.
6. Numerous additional tests and certificates are required to support the authenticity of FR cables, such as ULC S-139, IEC60332, MIL-DTL-24643. This does attract some additional dollars.

VIII. POWER CABLES VS CONTROL CABLES IN LOW VOLTAGE SYSTEMS

Power cables have always been earmarked or type casted as more important, superior, and precious than control cables. A lot of stress and importance has been given on optimal sizing of power cables. But it is important to know thatfor considerable number of cases in the LV system,the control cables, particularly their impact on cost needs to be assessed

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through the same lens as used for power cables. This section of the paper is to attract attention towards cases where control cables are found costlier than the power cables. This happens mostly in low voltage level.

Below Table 8.1 has blue arrows where a power cable in 415V is found lower or almost equal to the price of control cable associated with it. Therefore, significant effort should be reserved for optimizing the control cables as well (no. of cores/ pairs), based on the requirement of control signals for those specific loads.

	Armored Power cable PVC/XLPE Aluminum conductor	Price that vendor quote in EPC (INR /meter)
415V	3CX2.5	66.5
415V	3Cx25	109
415V	3Cx35	145
415V	3Cx50	177
415V	3CX70	233
415V	3CX95	289
415V	3CX240	1064

	Paired Cable (Overall shielded + Inner shielded), **Armored Copper conductor**	Price that vendor quote in EPC (INR /meter)
Control	2PX2.5	139
Control	3PX2.5	189
Control	4PX2.5	238
Control	5PX2.5	289
Control	6PX2.5	339
Control	4CX2.5	108
Control	6CX2.5	150
Control	7CX2.5	169
Control	8CX2.5	191
Control	10CX2.5	223
Control	12CX2.5	260

Table 8.1

IX. PAIRED CONTROL CABLES VS CORE CONTROL CABLES

The most noticeable difference between a paired cable and a core cable is the construction, specifically the conductors. A multi-conductor cable consists of multiple cores, while a multi-paired cable (commonly referred to as twisted paired cables) has the conductors twisted into pairs of 2 or 3. For the length of the wire, the two wires of each pair are bonded or adhered together, which results in a uniform spacing from conductor-to-conductor. This uniformity can be beneficial for several reasons, including easier manipulation and installation while avoiding affecting performance. Furthermore, these cables have been designed to undergo stress that occurs during normal installation. With the two wires of each pair unadhered, kinks and pulling can damage the physical and electrical properties of the cable, whereas with the 2 wires bonded, the physical properties are preserved. Furthermore, they are more durable, and therefore cost-efficient in the long term. Additionally, each bonded pair of the paired cable can be shielded, while an overall shield is also present. These shields protect the wires from electromagnetic interference. Shielded cables are particularly adept at eliminating most crosstalk. Unshielded twisted pair cables only with an overall shield also exists, that are more flexible and easier to install, but do not have some capabilities of shielded.

The above section gauges that shielded paired control cable should demand some price premium over the core control cables. For an appropriate price comparison, a 6C cable has been considered equivalent to a 3P, 10C equivalent to a 5P, and likewise. As per the available data from past project experiences and cable suppliers price list, an overall shielded and individual shielded paired cable is priced **25-30%** higher than its equivalent cored cable.

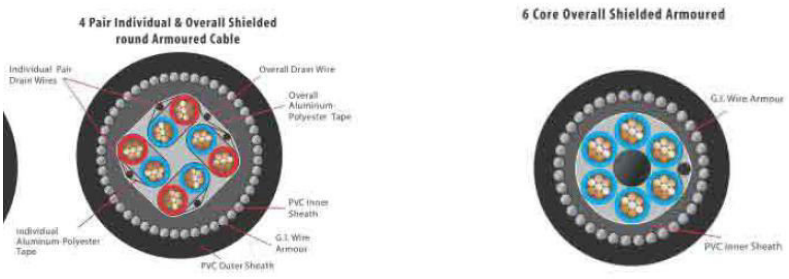

Figure 9.1

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X. STANDARD CABLE DRUMS VS NON-STANDARD CABLE DRUMS

The debate around standard cable drums vs non-standard cable drums generally surfaces up when small quantum of cables is in consideration in a small project or during a change order in a large ongoing project. This scenario is mostly applicable in LV cablesas in MV or higher, cable drums are generally customized or say non-standard. While there is no percentage price variance that can be affirmed between the two kinds of drums for LV cables, the below section can assist in establishing the overall cost-benefit analysis between standard and non-standard cable drums.

In standard drums, the delivery is fast, the pricing from the vendor is standard and more negotiable. Also, the cable drum management in the warehouse at the construction site is less cumbersome and less time consuming as any drum of that cable size and length can be utilised at site. In case of delays in cable delivery, this benefit can be further much better experienced.

In non-standard drums, the cable wastage is greatly reduced and leads to value engineering for owner and EPC contractor. However, as it is a non-standard entity for the cable OEM, the delivery might get delayed, or lead time can be higher. Also, the cable price per unit length tends to be higher than that of a standard drum which is generally of higher length. Furthermore, as the dimension of non-standard drums is varying, the logistics and transportation may need to be visited.

XI.CONCLUSION

Awareness on commercial aspects of cables shall be an imperative thing for the design consulting professionals. Cables are sometimes oversized as there are lot of contingencies considered at every step because it provides a fall-back cushion to the engineers for any kind of under-estimation in load or additional requirement discovered later. However, there is anextra cost and expenditure that gets aggregated eventually across the project. Therefore, while arriving at any decision around cable size selection, the perspective from the commercial side should also be factored in and this is what this presentation targets to bring to the table for the readers.

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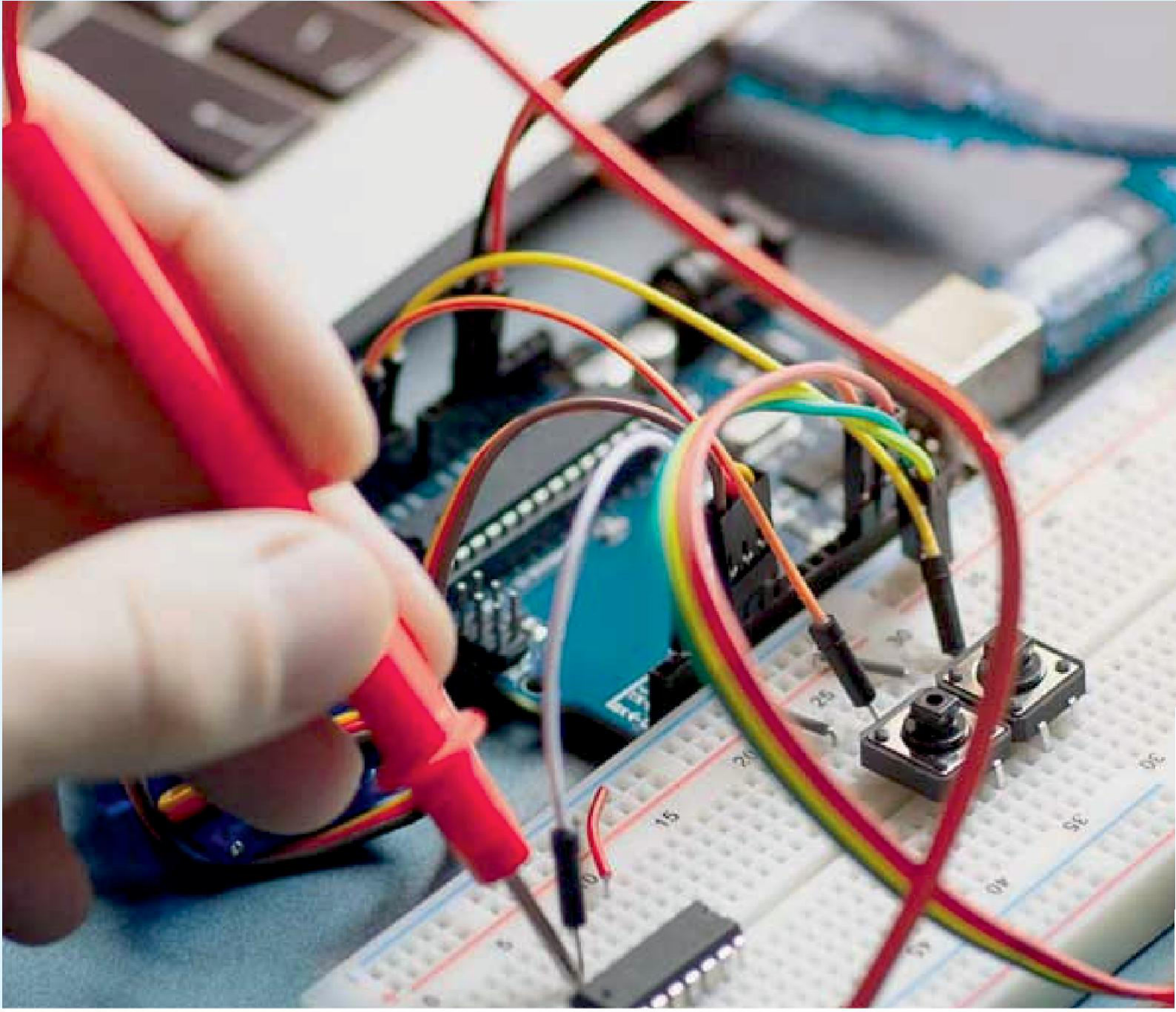

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