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A Review on Solar PV Based Multilevel Inverters

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ABSTRACT: There has been a groom in technological development of grid integration of renewable resources (RR). The two main causes for sudden increase of grid integration of RR, first scarcity in availability of conventional resources and another is that non-conventional resources are clean and green form of energy. The expanding weight on the need to heighten the support of cleaner types of energy to blend with the existing transformation frameworks, especially wind, small hydro and solar . This paper comprises of many different topologies in multilevel converters along with renewable energy systems. Power generation from solar PV system fed to multilevel converter has gained popularity among the researchers as it has the concept of increasing the levels of converter which results in more smooth waveforms and gradually an approach to reduce filters and thus the system can be economical.

KEYWORDS:- Solar Photovoltaic (PV) system, Multilevel converter, Total Harmonic distortion (THD)

I. INTRODUCTION

MLIs are drawing attention in research and industry, as they are changing into a viable technology for several applications. The concept of MLI was developed for high power and high/medium voltage applications since they provide an effective interface with renewable energy sources. MLI is preferred over traditional inverter because of numerous advantages. Technical advancement in power electronics has commenced to improve the level of inverter to cater to the need of medium voltage high power applications without transformer. There applications reduce the harmonics problem with reduced voltage stress across the switch. On the other hand, MLI feature several DC-links due to which independent voltage sources can be used. t the solar photovoltaic (PV) sources are primarily used in the MLI. In case of CHB there are multiple DC voltage sources are required and the solar PVs are best suited for it. But there are number of maximum power point tracking (MPPT) system are required in case of solar PV based generation system, where MLI is used in the power conditioning unit (PCU) for converting DC into AC with lesser THD. In that case the solar PVs are used with the NPC, because of this control and the tracking of the MPP in each string become easier. In case of industrial applications the CHB is better choice with multiple solar PVs for drives applications as CHB produces fewer harmonic and for electricity generation system whether it is stand alone [5] or grid connected [1-4] NPC is preferred to CHB, as NPC requires less MPPT sensors. Numerous literatures are deals with the solar PV based MLI, where most popular are NPC and CHB. In this thesis performance of both NPC and CHB are analyzed with solar PV inputs.

The other aspect of utilizing solar PV as a source of MLI is to promote renewable energy. As solar energy is most promising source of energy, in India where solar generation is fast developing.

II. SOLAR PHOTOVOLTAIC SYSTEM (SPS)

The main sources of world energy generation are the fossil fuels and due to their exhaustive usage they are obsolescing moreover, their wide usage is emitting greenhouse gases (CFC, CH4, O3, but mainly CO2). Renewable energy sources (RES) are eco friendly and sustainable form of sources. The RES are sufficient enough to match the world energy requirement. The most commonly used RES are:

- Photovoltaic
- Wind Power
- Small Hydropower
- Biomass
- Geothermal
- Hydrogen Power

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Photovoltaic (PV) [2-5] is a very popular form of RES which can synthesize electricity without any thermal or electro-mechanical interlink. When a cluster of solar modules are assembled at a place, it results in a solar panel. The energy generated from this integrated module group is referred as solar power. The solar cells are also known as photovoltaic cells or the PV cells. As the name itself suggests, photo means light while voltaic refer to electricity. Solar cells are electrical devices in the solid form that help convert energy from sunlight into electric energy with the help of photovoltaic effect. When a number of solar cells are clustered together, they are called solar modules which together save energy from sunlight. When a cluster of solar modules are assembled at a place, it results in a solar panel. The energy generated from this integrated module group is referred as solar power. The solar cells are also known as photovoltaic cells or the PV cells. As the name itself suggests, photo means light while voltaic refer to electricity. In other words, photovoltaic cells can help tap into the potential of solar energy to generate electric current. PV cell generates low voltage of around 0.5V,hence they are connected in series for high voltage and shunted for high current requirements to form a Solar-PV module for desired output separate diodes may be required to avoid reverse currents.

III. MULTILEVEL CONVERTER

The MLI offers several feature which raises its demand in present scenario such as; possible connection of series switching devices to obtain a high voltage output without the need of snubber circuit, significantly low THD in output waveforms, use of IGBT as switching device at high frequency to reduce losses, reduced torque ripple in induction machine etc..

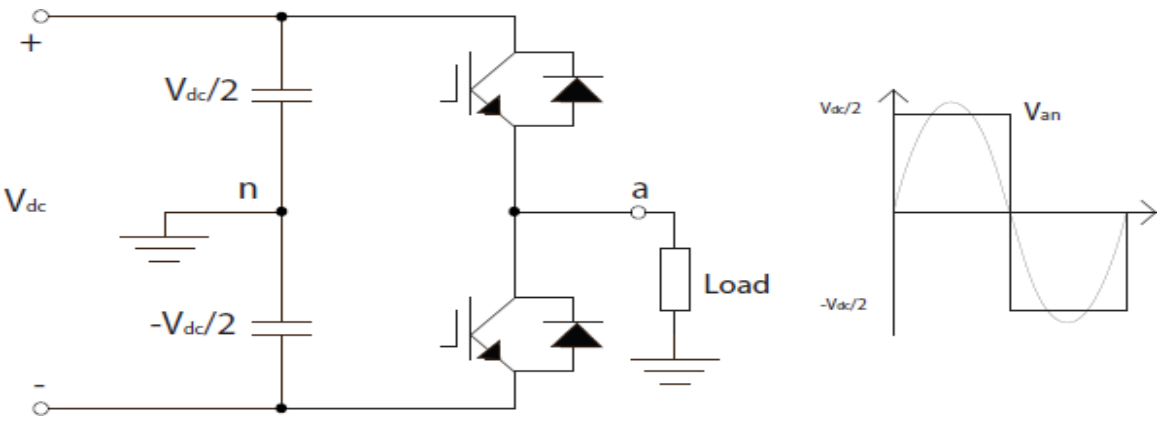

Figure 1.1 One phase leg of a two-level inverter and a two-level waveform

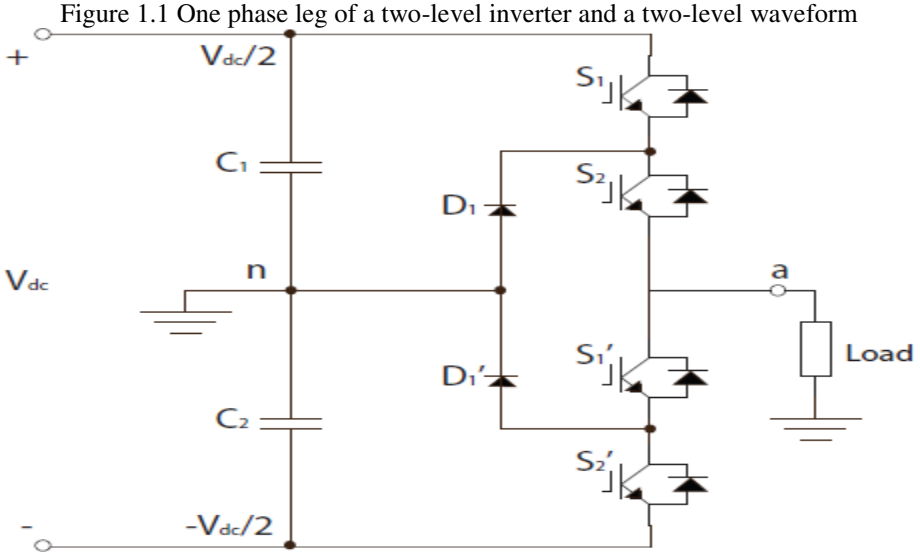

Figure 1.2 one phase leg of a three-level inverter and a three level waveform

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Numerous topologies are available in literature for MLI which has been classified in figure 2. Among all available topologies the widely used MLI are CHB-MLI and NPC-MLI. In this thesis simulation model of PV array is developed using simscape.

A) Diode / Neutral Point Clamped (NPC) Topology

The diode clamped converter provides multiple voltages through connecting the phases to a series capacitors banks. The concept can be increased to number of levels by increasing the number of capacitors. Earlier this methods was only limited to three levels in which two capacitors connected across the dc bus resulting in one additional level that is the neutral point, so the terminology NPC-MLI was introduced in the theories.

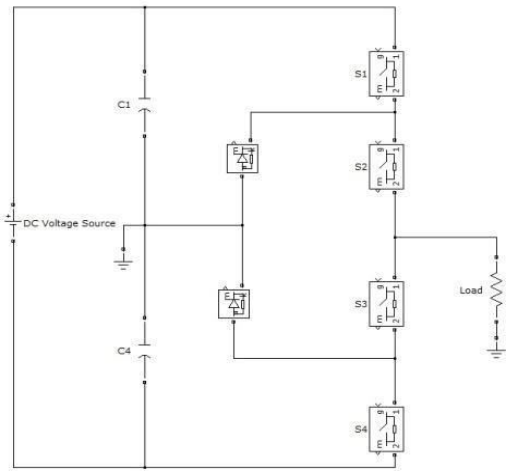

Figure 1.3 Three level diode clamped MLI

B) Flying Capacitor (FC) Topology

The flying capacitor involves series connection of capacitor clamped switching devices. This has several advantages when compared to the NPC topology such as no additional clamping diodes are required. Further, the flying capacitor converter has switching redundancy in the phase which is employed to balance the FC hence only one dc source is required.

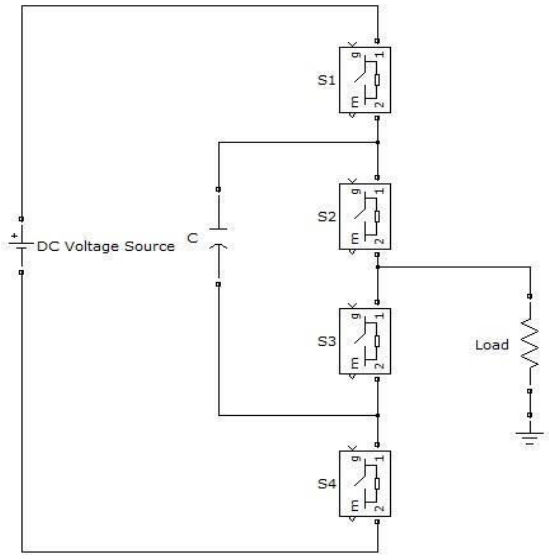

Figure 1.4: 3-level FC topology

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C) Cascade H-Bridge (CHB-MLI) Topology

In cascade H-bridge there are several different configurations as well. This topology consists of series power conversion units, the voltage and power level may be conveniently scaled. The biggest limitation of CHB is large number of isolated voltages are required to supply each cell unit separately [8-15]. In this study focus is on the increasing different levels in converters starting from basic three levels to the nine levels with their simulated results giving a comparison on using two different topologies NCP and CHB type.

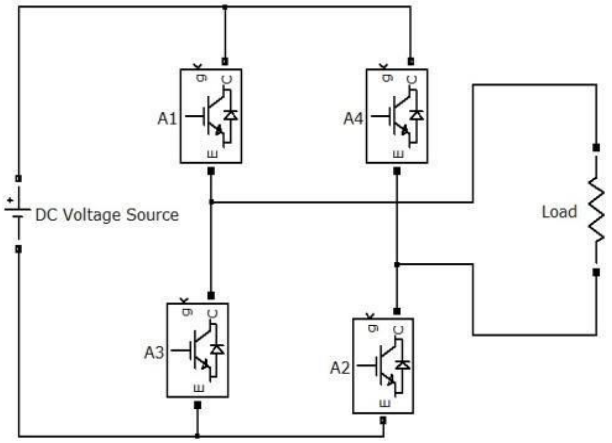

Figure 1.5: 3-level CHB-MLI

IV. MODULATION TECHNIQUES

Now a day‟s mainly the power electronic converters operates in the “switched mode”. Which means the switches within the converter is operated in either one of the two states turned off means no current flows and turned on means a small voltage drop across the switch. The switched component is attenuated and the desired AC component is retained from it. This is Pulse Width Modulation (PWM) [8]. The basic classification of modulation techniques [1] of MLIs are depicted in figure

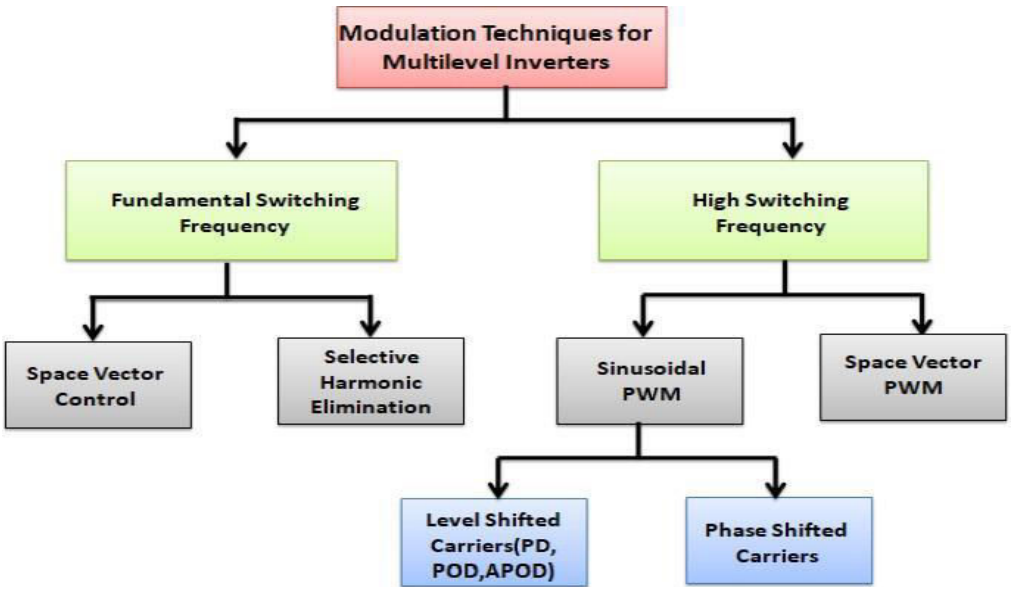

Figure 1.6: Basic Modulation techniques for MLIs

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The Sinusoidal Pulse Width Modulation (SPWM) is a popularly used in high switching frequency technique. The SPWM is a simple technique that is used to a sequence of voltage pulses by consequent turning on/ off of power electronic switches in a converter [31]. This technique results in generating pulses of constant amplitude but with varying width. The technique involves comparing a reference sine wave (Vr) with a high frequency triangular carrier wave (Vc). The instants of switching and commutation of the switches is determined by the points of intersection of reference and carrier waves The SPWM techniques when implemented for multilevel inverters require more number of carrier waves. Multicarrier PWM is used when deals three level or higher levels in inverter output. In multilevel PWM a reference signals having sinusoidal characteristic is naturally sampled with the help of a number of carrier signals. An *N*-level MLI requires *N-1* carrier signals to sample the signal and generate the switching pulses for the power switches incorporated in the inverter. These power switches then operate accordingly to produce the required multilevel output. For an *N*-level inverter, *N-1* carriers with the same frequency *fc* (or may have different frequency) and the same amplitude *Ac* are disposed such that the bands they occupy are contiguous. The reference waveform has peak-to-peak amplitude, a frequency and its zero centered in the middle of the carrier set.

A) Level Shifted PWM (LS-PWM)

The basic extended form of 2-level PWM for *N*-level MLI is LS-PWM. Instead of one carrier signal, *N-1* carrier signals are employed which are shifted vertically to each other. Since each carrier has two levels, the same principle of 2-level PWM can be applied, taking into account that the control signal has to be directed to the appropriate power switches in order to generate the corresponding levels in the output. A LS-PWM can be implemented in three different ways:

- **Phase Disposition (PD-PWM):** wherein all the carrier signals are in same phase.
- **Phase Opposition Disposition (POD-PWM):** wherein the carrier signals above the zero are out of phase with those below the zero by 180º.
- **Alternative Phase opposition Disposition (APOD-PWM):** wherein nearby carrier signals are 180º out of phase.

LS-PWM gives less harmonic distortion for the line-to-line voltage. However, this strategy generates uneven switching frequency and unequal device conduction period which can affect the charging and discharging of the DC-link capacitors thus resulting in their unequal loading. Examples of these methods for a 5-level inverter are shown in Figure 1.7 to Figure 1.9.

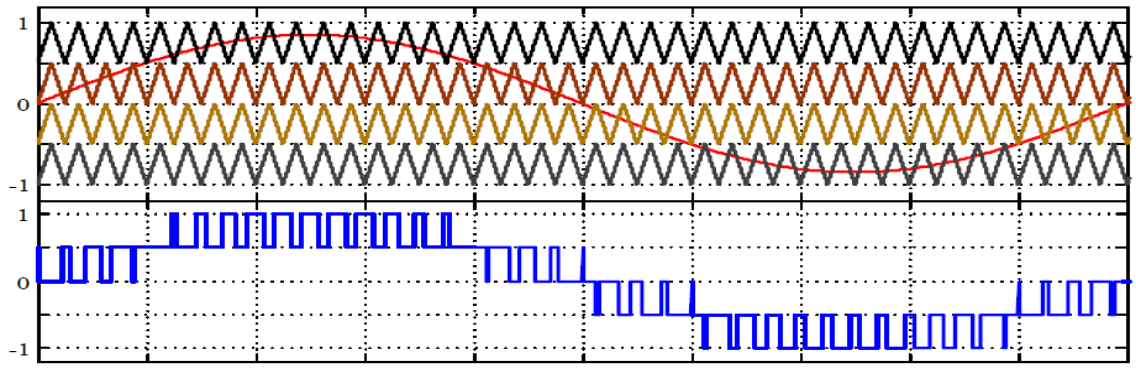

Figure 1.7 PD-PWM

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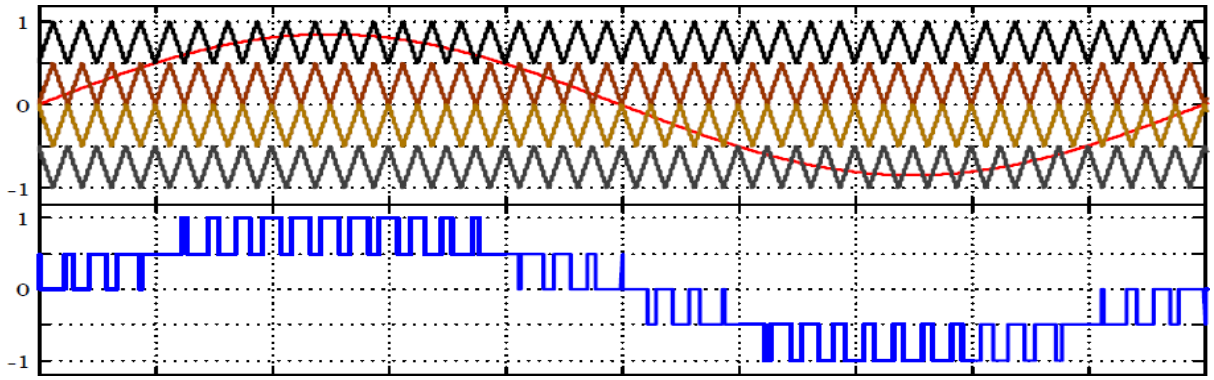

Figure 1.8 POD-PWM

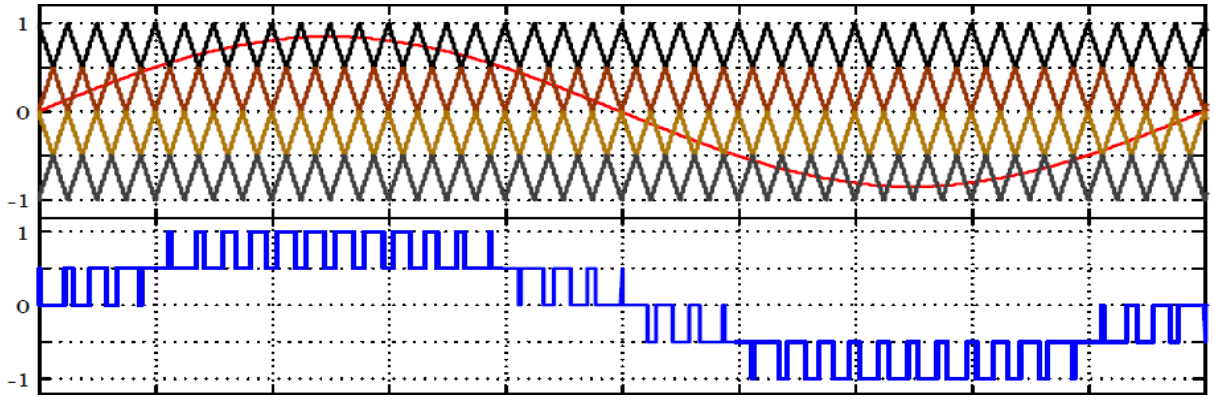

Figure 1.9 APOD-PWM

B) Phase Shifted PWM (PS-PWM)

In this strategy of modulation, the carrier signals are shifted in phase with respect to each other which are then compared with the reference signal. Similar to LSPWM, N-1 carrier signals which have the same frequency and peak-to-peak amplitude are required for the modulation of an N-level inverter where the phase shift Φs between the adjacent carrier signals.

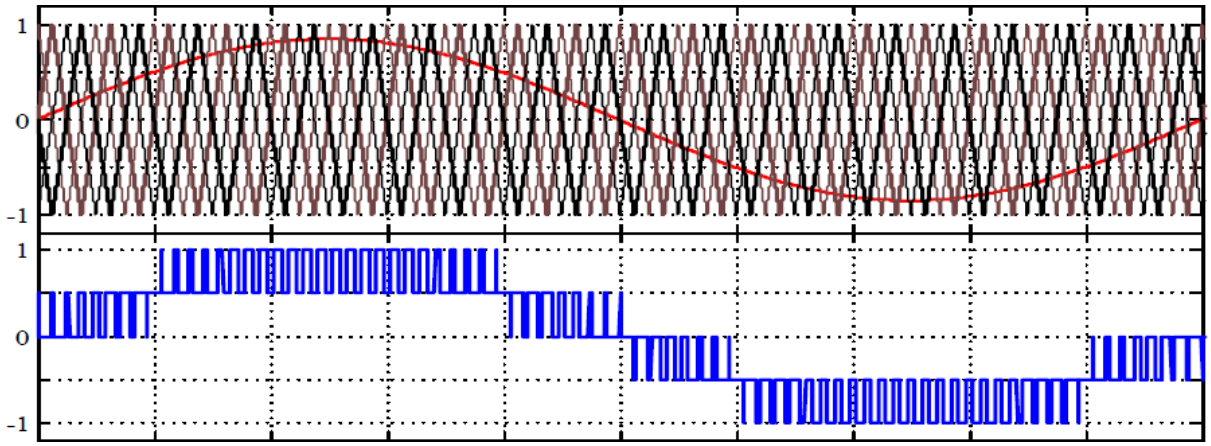

Figure 1.10 PS-PWM

However, it is perfectly suitable for CHB and FC MLI topologies as they possess switching redundancies. Also in PS-PWM, switch device usage is evenly distributed which allows for equal loading of DC-link capacitors. This method

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leads to higher distortion in the line voltages compared to LS-PWM. Figure 3.10 depicts the phase-shift modulation of a 5-level.

V. CONCLUSION

In this paper we have studied about related to solar photovoltaic array, panels, module starting from the working of solar cell and also contains the introduction to MLIs, its classification and the PWM switching scheme of the devices used in that. Single-phase voltage source MLI has discussed in details along with the discussion on the sinusoidal PWM. Nowadays, more interest is MLI control because of its wide range of applications in the development of the power Electronics. This paper provides a general analysis of all the works related to Solar Based Multilevel inverter that has been done in the recent past.from above all literature reviews it has found that
to improve the performance of the system in a way to reduce losses, distortion and to enhance the efficiency by using different topologies of MLIs. The two most preferred topologies are neutral point clamped (NPC) and cascade H-bridge (CHB). The NPC-MLI find applications in Static VAR compensation, Variable speed motor drives, High voltage DC-AC transmission lines and applications of CHB-MLI are Motor drives, Active filters, Electric vehicle drives, DC power source utilization, Power factor compensators, Back-back frequency link systems and Interfacing with renewable energy resources.

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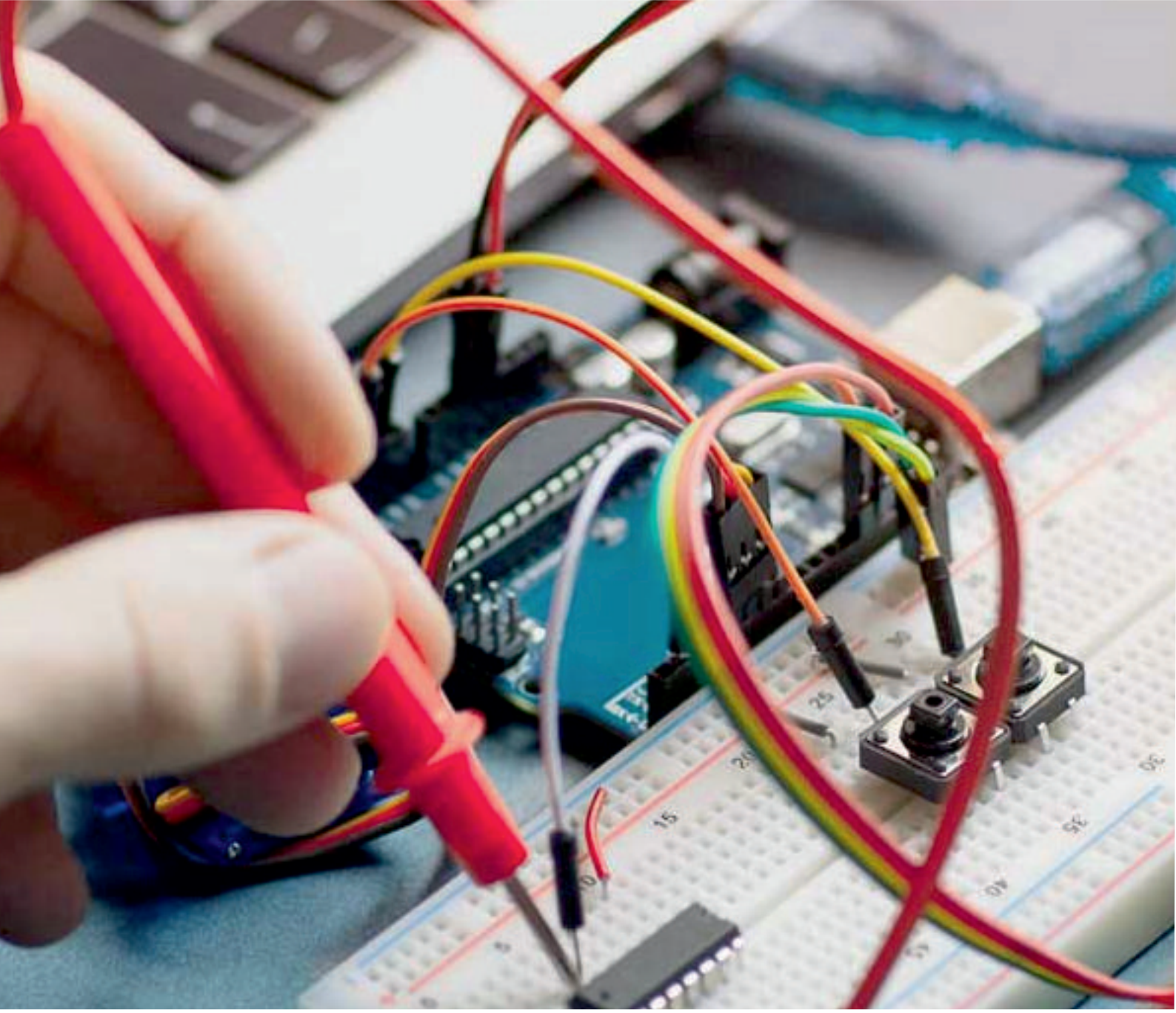

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