EMC Compliance for Renewable Resource Power Systems

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Contents

Introduction 2
Renewable Resources 3
    Biomass 3
    Geothermal 4
    Hydroelectric 5
    Solar energy 6
    Photovoltaic (PV) 6
    Concentrating solar power (CSP) 7
    Tidal power 8
    Wave power 8
    Wind 9
EMC Considerations 10
    Environments and Installations 10
    Emissions 13
    Susceptibility 16
    Powerline communications 18
    Wireless communications 19
Summary 20

About Intertek 21

Introduction

Renewable resources such as plants, sunlight, wind, rain and geothermal heat are naturally replenished over time – as distinguished from the finite resources coal, oil and natural gas. The market forces driving the development of renewable resources vary by region of the world, but they include:

- Reduction of greenhouse gases;
- Reliability of existing power network;
- Depletion of petrochemical sources;
- Local regulations, tariffs, subsidies and tax incentives.

The scale of cost-effective power generation from renewable resources varies by type, and it can range from small rooftop photovoltaic (PV) solar cell installations generating a few kilowatts (kW) for local consumption (see photo below) to an offshore wind farm producing hundreds of megawatts (MW) peak and distributed over the high-voltage electricity grid to thousands of users. Often, renewable resource utilities will use more than one technology, to assure a more uniform supply of electric power over a 24 hour period.

Not all renewable resources need to be converted into electrical power to be useful. For example, geothermal heat is widely used for both heating and cooling on a local basis. Fluid-filled solar panels can similarly provide home heating. Using the renewable resource to generate electricity, however, multiplies its versatility in terms of applications, customers served, and electrical utility power saved. In this paper we will focus on electricity generation using renewable resources.

Each of these renewable resource electrical power systems has its own unique electromagnetic compatibility (EMC) characteristics – RF emissions and immunity - in addition to issues of environmental and electrical safety. Most jurisdictions around the world (in the USA for example, the FCC) regulate radio interference from electrical and electronic equipment, and many also govern immunity (as in the EU) to assure that the equipment continues to operate as intended in the presence of interference from other equipment including radio transmitters. Standards also cover EMC requirements for grid-connected or grid-tied power sources, where the renewable resource feeds electrical power back into the utility network.

Renewable Resources

Today, renewable resources account for about 18% of the global electricity generation market. Some segments such as PV and wind power are growing more rapidly than others, but all segments are experiencing substantial investment. Estimates of the present capacity and potential for renewable resources are given in Table 1 below, followed by a brief overview of the most common renewable sources of electrical power.

Total global electricity consumption is estimated at 15 TW, which can be supplied many times over by only partial realization of renewable resources.

Renewable source	2010 generating capacity, Gigawatts (GW)	Global generating potential, Terawatts (TW)
Biomass	54	46
Geothermal	11	22
Hydroelectricity	480	7
Solar photovoltaic (PV)	21	1000
Solar concentrated (CSP)	500	
Tidal power	50 MW	10
Wave power	10 MW	2
Wind	175	72

Table 1 – Estimated global capacity and potential for renewable resource electricity generation.

Biomass

The term biomass includes fuels derived from timber, agriculture and food processing wastes or from fuel crops that are specifically grown or reserved for electricity generation. Biomass fuel can also include sewage sludge and animal manure. Biomass can be converted into other forms of energy through chemical processes such as fermentation, but for the purpose of electricity generation direct combustion is generally used. Some air pollution can be created, so biomass power plants may be less “green” than other renewable resources.

Biomass is widely used for individual heating and cooking. It is estimated that 40% of the world’s cooking stoves use biomass. However, biomass power plants are typically utility-scale (output > 200 kW) and are not suitable for individual residential use. The photo at left depicts a 24 MW plant. Steam-electric generators, also used in fossil fuel power plants, provide the electrical power output from biomass plants. Although the power plants themselves are exempt from most EMC regulatory requirements (except to not cause interference), their internal control equipment performs critical functions that demand adequate immunity from industrial electromagnetic disturbances. The electrical output of the plant must conform to utility standards for power quality. Figure 1 illustrates a typical plant block diagram.

Geothermal

Hot springs, geysers and ancient Roman baths are all examples of geothermal energy. This energy source can be tapped directly for individual residential purposes without generating electricity, by using heat pumps. At the utility level, geothermal power plants convert hydrothermal fluids (hot water or steam) to electricity. The oldest type of geothermal power plant uses steam, accessed through deep wells, to directly drive a turbine to produce electricity. Flash steam plants are the most common type of geothermal power plants in operation today. They use extremely hot water (above 300 degrees F), which is pumped under high pressure to the generation equipment at the surface. The hot water is vaporized and the vapor in turn drives turbines to generate electricity. Binary-cycle geothermal power plants use moderate-temperature water (100-300 degrees F). The water is used to vaporize a second fluid that has a much lower boiling point than water. The vapor from this second fluid is then used to drive the turbines to produce electricity.

As with biomass generating plants, the geothermal power plants themselves are exempt from most EMC regulatory requirements; their internal control equipment performs critical functions that demand adequate immunity from industrial electromagnetic disturbances. The electrical output of the plant must conform to utility standards for power quality. Figure 1 below illustrates a typical plant block diagram.

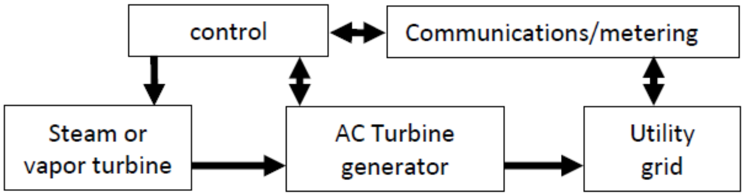


Figure 1 - Block diagram of biomass or geothermal electricity generation system.

Hydroelectric

Many hydroelectric power plants use a dam on a river to store water. Water released from behind the dam flows downhill through a turbine, spinning it, which then turns a generator to produce electricity. Hydroelectric power does not require a large dam – some hydroelectric power plants use only a small channel to direct the river water through a turbine. A small or micro-hydroelectric power system (< 100 kW) can produce enough electricity for a home or farm. Water is 800 times denser than air, so it is a very efficient source of power where it is available.

Small or micro-hydroelectric plants are often used off-grid, where the power will be consumed locally. DC generators or alternators can be used where AC power frequency is unimportant. If the hydro power is to be fed back into the utility grid, or otherwise where line frequency is critical, then the power plant must incorporate any of: 1) an automatic controller at its inlet valve plus an alternator, or 2) an induction generator synchronized to the utility power, or 3) a solid-state inverter accepting either DC or variable-frequency AC and synchronized to the utility power.

The control systems in small or micro-hydroelectric installations may be subject to residential or commercial electromagnetic emissions limits, as well as immunity. Grid-connected or grid-tied systems are subject to utility power quality requirements. Large hydroelectric plants will generally be exempt from EMC standards, but their internal control systems must meet industrial EMC standards in order to provide adequate operating reliability.

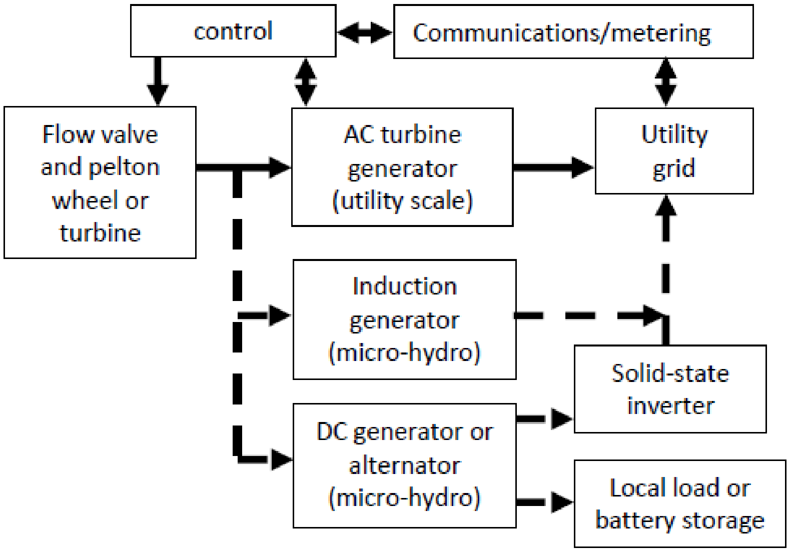


Figure 2 – Block diagram of hydroelectric utility and small-scale plants.

Hydroelectric storage – pumping water uphill for later release – is often used in conjunction with renewable resources that are periodic in nature, such as solar, in order to provide a more uniform flow of electrical power to the user.

Solar energy

Around the world, several kilowatt-hours per day of solar energy fall on every square meter on the surface of the earth. The exact amount depends on latitude and weather, but the total constitutes vastly more power than that presently consumed.

The conversion of solar power into useful energy usually takes one of two paths: 1) direct use by heating, either locally with fluid-filled solar panels or at utility scale by concentrating solar power (CSP or solar thermal); or 2) using silicon photovoltaic (PV) panels to generate DC electricity either for residential purposes or at utility scale. The DC power is usually converted to AC power using solid-state inverters. Inverters are available with capacities ranging from a few kW for residential applications to MW for utility plants. Large-scale CSP is more efficient than PV at converting solar energy to electricity, but the difference is diminishing as solar cell technology advances.

Photovoltaic (PV): A number of different silicon fabrication technologies (such as thin film, monocrystalline silicon, polycrystalline silicon, and amorphous) are used in assembling panels to convert solar energy to DC electrical power. The current-voltage characteristics of each panel are a function of the incident solar energy, with output short circuit current and open circuit voltage increasing with increasing light level. Maximum power is derived from each panel when the product of voltage and current outputs are maximized. Most inverters intended for PV applications will have built-in power maximization circuitry. Most residential and utility scale solar PV installations (such as the megawatt-scale installation shown above) keep their panels in a fixed orientation for the sake of simplicity, even though tracking the position of the sun can add up to 50% in output.

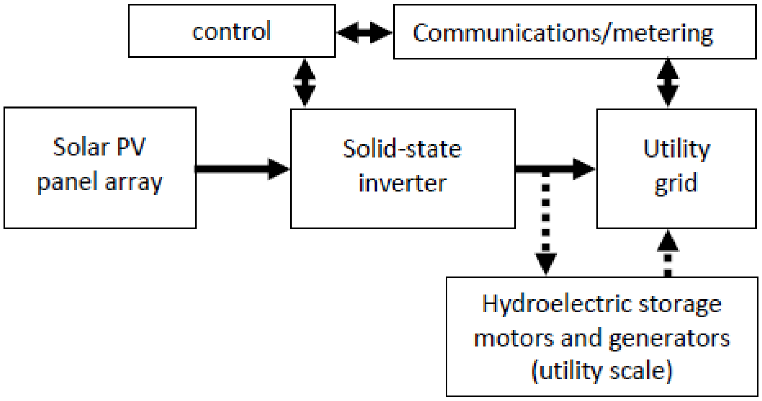


Figure 3 – Block diagram of photovoltaic power system.

The control systems and inverters in residential or small commercial PV systems are subject to residential or commercial electromagnetic emissions limits, as well as immunity requirements. Grid-connected or grid-tied systems must meet utility power quality requirements. Large PV plants will generally be exempt from EMC standards, but their internal control systems and inverters must meet industrial EMC standards in order to provide adequate operating reliability. Solid-state DC-to-AC inverters employ high-power switching circuitry, which can generate radiated and conducted interference unless adequately shielded and filtered.

Concentrating solar power (CSP) or solar thermal: Concentrating solar power (CSP) technology is used solely in utility scale plants. It works by capturing the solar energy with a number of concentrating mirrors or lenses, and uses the resulting heat to create steam and then electricity by a turbine generator. The most common forms for concentrating the sun's energy are linear solar troughs (parabolic in cross-section), solar dishes (similar to satellite dishes) and solar towers surrounded by a field of reflectors called heliostats as in the photo here. Temperatures of up to 1,500˚C may be generated in an intermediate heat transfer working fluid that may be oil or molten salts, and finally into steam for the turbine. Molten salts have the added advantage of storing heat to generate steam during cloudy weather or at night.

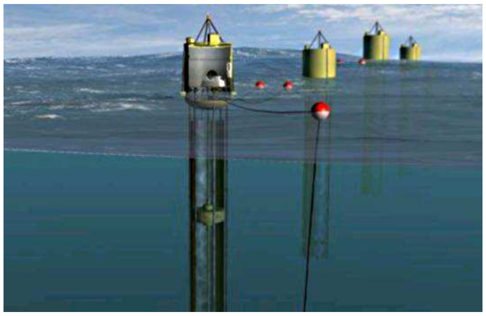
Figure 1 also serves as the block diagram for the power generation part of CSP systems. The trough reflectors, dishes, heliostats and lenses used in CSP systems track the position of the sun during the day, to maximize solar power conversion. This adds some complexity to the overall system. CSP plants will generally be exempt from EMC standards, but their internal control and tracking systems must meet industrial EMC standards in order to provide adequate operating reliability.

Tidal power

Owing to the gravitational pulls of the earth's moon and sun, ocean tides flow twice a day in and out of natural estuaries or man-made channels. This flow of water can be harnessed by submerged turbines similar to wind turbines as a reliable source of electrical energy. Although a number of tidal power prototypes have been deployed, this is a relatively new technology and only one tidal power system, shown in the illustration at left, has been deployed commercially in the UK. The system can generate up to 1.2 MW of power; rotor blade angle control allows the system to generate regulated AC power for tidal flow in both directions.

Tidal power plants themselves are exempt from most EMC regulatory requirements; their internal control equipment performs critical functions that demand adequate immunity from marine electromagnetic disturbances, including shipboard radars. The electrical output of the plant must conform to utility standards for power quality.

Wave power



It has been estimated that favorable coastal locations contain about 50 kW per meter of shoreline in available wave energy. This energy is not as steady or predictable as tidal power; in fact, it has many of the same characteristics as wind power. A number of different approaches have been tried to harness wave power, but few have been commercialized so far. One method employs a float inside a buoy that moves up and down with the waves, working an internal plunger that is connected to a hydraulic pump. The pump drives a generator to produce electricity, which is sent to the shore by means of an undersea cable.

Owing to the variability of the power source, wind power systems are often grid-connected through a solid-state inverter that can assure constant AC frequency and waveform. Wave power plants themselves would be exempt from most EMC regulatory requirements; any internal control equipment would need adequate immunity from marine electromagnetic disturbances, including shipboard radars if located far offshore. The electrical output of the plant would have to conform to utility standards for power quality.

Wind

Wind power is similar to PV solar power in being available everywhere, and in being scalable from individual residential wind turbines at the kW level to utility plants generating 100 MW or more. The offshore wind farm at left can generate 300 MW, and includes its own offshore power substation. A typical individual wind turbine will include a rotor, gearbox and generator. The gearbox is used to increase the slow rotational speed of the rotor to higher generator speeds suitable for providing AC line frequency power from an induction generator. Electronic rotor pitch control is often used, especially in large-scale systems, to optimize power generation efficiency and provide speed reduction and stopping under very high winds and for servicing.

Single residential or farm turbines may use a DC generator or alternator for battery recharging, or with a solid-state inverter for grid-tied or grid-connected power feeding. Typical wind power systems are shown in the block diagram in Figure 4 below.

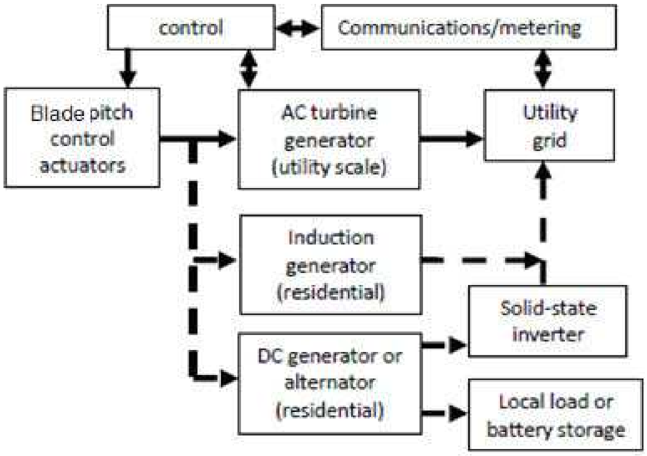


Figure 4 – Block diagram of small-scale and utility-scale wind-power systems.

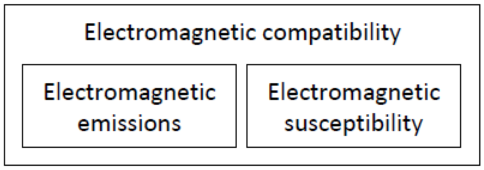
The aggregated power from utility scale wind farms is converted to HV for transmission over the utility's HV (> 100 kV) lines.

The control systems and inverters in residential or small commercial wind power systems are subject to residential or commercial electromagnetic emissions limits, as well as immunity requirements. Grid-connected or grid-tied systems must meet utility power quality requirements. Large wind farms will generally be exempt from EMC standards, but their internal control systems and inverters must meet industrial (or marine, if located offshore) EMC standards in order to provide adequate operating reliability. Solid-state DC-to-AC inverters employ high-power switching circuitry, which can generate radiated and conducted interference unless adequately shielded and filtered.

EMC Considerations

Environments and Installations

In the USA, electromagnetic emissions are regulated by the Federal Communications Commission (FCC) in order to prevent interference to radio and TV broadcast reception, and to sensitive services such as radio astronomy and radio navigation. Susceptibility is not regulated by the FCC – but there are medical, military, aerospace, automotive and some other industry standards. In the EU, both emissions and susceptibility are regulated under the EMC Directive 2004/108/EC to assure the free movement of goods.



Typical EMC environments can be classified by the severity of the electromagnetic disturbances normally found there (for susceptibility), and by the distance to the boundary within the operator's jurisdiction (for emissions).

- Residential environments usually assume a boundary 10m away, and by household sources of disturbances. In the USA, residential emissions from RF and digital devices are regulated under FCC Part 15, Subpart B, Class B limits. In the EU, residential EMC requirements also extend to commercial and light industrial environments. Thus a home rooftop solar PV system containing electronics such as a solid state inverter falls under residential emission limits.

- Industrial environments are generally based on a 30m boundary, and have disturbances from high-power switchgear, arc welding equipment and similar electromagnetically-noisy sources. In addition, industrial environments are often differentiated from residential ones in being connected to a medium-voltage (MV) power transformer as opposed to a 120/240 V low-voltage (LV) distribution transformer. In the USA, industrial emissions from RF and digital devices are regulated under FCC Part 15, Subpart B, Class A limits.

When electrical or electronic equipment is located in a large area under one jurisdiction, such as in a public utility or industrial plant, most interference problems from the equipment can be resolved within the area and without regulatory intervention. Hence the FCC exempts such equipment from its technical rules. The corresponding classification under the EMC Directive in the EU is a "fixed installation" to which CE-marking does not apply. Utility-scale biomass, CSP, geothermal and PV plants are not subject to FCC or EU EMC limits except for the general requirement to not cause interference. However, the control equipment within these plants performs critical functions and should conform to appropriate industrial EMC standards such as EN/IEC 60947-1 (low-voltage switchgear and controlgear) EN/IEC 61326-1 (process control and measurement), or IEC TS 61000-6-5 (immunity for power station and substation environments).

The potential electromagnetic interactions between devices in an installation and with external influences are indicated in Figure 5 below. Disturbances can enter and exit equipment by way of AC or DC power wiring, or over signal and control cables. Radio frequency (RF) emissions can emanate from equipment enclosures and disturb nearby equipment, or exit the installation boundary to cause interference to radio/TV or other sensitive receivers not under the control of the renewable power system operator. Similarly, RF emissions from powerful broadcast stations or nearby cell phones can upset the monitoring or control systems of the renewable power system. When the components of a renewable power system (such as Unit 1 and Unit 2 in the figure below) do not interfere with each other, they are termed electromagnetically self-compatible.

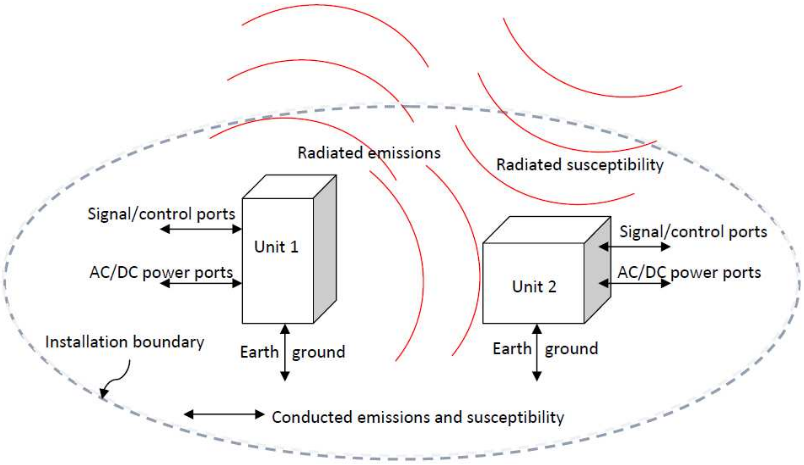


Figure 5 – Potential electromagnetic interactions between equipment and environment.

Table 2 below summarizes electronic equipment EMC standards for various environments for the USA and EU. Note that the scopes of US Class A and B emissions do not map directly onto the generic EU EMC scopes. Because renewable power systems generally include a variety of electronics that could fall under several different EU EMC standards, we have chosen to show the default or generic standards here.

Environment	**USA - FCC**	**EU – EMC Directive**	
	emissions only	**emissions**	**immunity**
residential	Part 15 Class B	EN 61000-6-3 (generic)	EN 61000-6-1 (generic)
commercial	Part 15 Class A		
light industrial			
industrial		EN 61000-6-4 (generic)	EN 61000-6-2 (generic)
public utility or industrial plant	No interference	No interference	Documentation of EMC considerations

Table 2 – EMC standards for US and EU environments.

Renewable power systems that are connected to the electricity grid, whether residential or industrial, are subject to additional EMC requirements to assure that the grid is not exposed to needless distortion or interference.

In the USA, UL 1741 applies to inverters, converters, controllers and interconnection system equipment for use with distributed energy resources such as small-scale photovoltaic and wind power systems. When these systems are grid-tied or grid-connected, UL 1741 specifies compliance with the requirements in IEEE 1547 (Interconnecting Distributed Resources with Electric Power Systems), which in turn calls out these susceptibility standards:

- IEEE Std. 37.90.2 (Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers); and
- IEEE Std. C62.41.2 (Recommended Practice on Characterization of Surges in Low-Voltage AC Power Circuits);
- Or, in place of C62.41.2, IEEE Std. 37.90.1 (Surge Withstand Capability Tests for Relays and Relay Systems Associated with Electric Power Apparatus); and
- IEEE Std. 62.45 (Recommended Practice on Surge Testing for Equipment Connected to Low-Voltage AC Power Circuits).

The net effect of these susceptibility standards is to impose EMC criteria similar to, and slightly more stringent than, EU EMC requirements for similar phenomena. For example, IEEE Std. 37.90.2 specifies a 20 V/m RF radiated immunity test, plus a keyed and 200 Hz modulated spot test, to simulate GSM cell phone effects. The comparable EU generic industrial susceptibility level is 10 V/m.

In the EU, EN 50178 applies to all types of electronic equipment for use in power installations. Internally it refers to the generic residential, commercial and light industrial or industrial EMC standards comparable to those in Table 2. EN 50178 is harmonized to the Low Voltage Directive 2006/95/EC but not the EMC Directive. EN/IEC 61727 covers the utility interface characteristics of photovoltaic systems; it applies the flicker emission standards EN/IEC 61000-3-3 (< 16 A/phase) or EN/IEC 61000-3-11 (> 16 A/phase) to the interface, plus current distortion limits that fall under the category of EMC phenomena. EN 61727 is not harmonized or associated with any EU directive.

Emissions

Electromagnetic emissions may be intentional or unintentional. Intentional emissions include radio signals from broadcast stations, cell phones, and remote control keys; or signals over power lines to control lights and appliances. Unintentional emissions can arise from sources such as DC motor brush noise, electromechanical switching or digital circuitry in computers and power systems. Separate emissions standards apply to intentional and unintentional radiators.

Induction motors and generators do not generate significant emissions, nor are they susceptible to most electromagnetic disturbances. Therefore, they are usually not a factor in renewable power system EMC considerations. The major sources of unintentional emissions in most renewable power systems are digital control electronics and solid state inverters. Both of these create emissions by rapidly switching internal currents. High harmonics of the fundamental switching frequencies are generated, up to tens or hundreds of megahertz.

The inverter functions by chopping its input current into a series of pulses of variable width (pulse width modulation, or PWM), where the width changes to approximate a power frequency sine wave, as in Figure 6. The pulse frequency is often in the range 15 – 20 kHz. The input current to the inverter may be d.c., as for a photovoltaic installation, or ac for a wind turbine. If it is ac, the current is first rectified and then chopped.

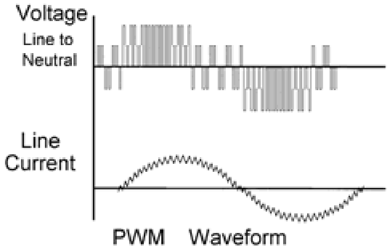


Figure 6 – Inverter switching waveform and output current

The high-frequency energy created by the chopping process, as well as the residual noise superimposed on the output current, must be adequately filtered to prevent excessive conducted and radiated emissions. EMC-compliant inverters usually contain robust EMI filters at their inputs, outputs and any signal or control connections. They are also well-shielded and employ other good EMC design practices.

Any rapid change in electrical current can give rise to an electromagnetic emission. If the current is traveling over a circuit board trace or wire of suitable length, that conductor can act as an antenna and radiate interference into the surrounding space. Long cables such as power cords are efficient antennas for frequencies below 30 MHz, so RF interference below 30 MHz is generally measured directly at the cable port as a conducted emissions voltage. RF interference above 30 MHz is usually measured with an antenna as electric field strength. Equipment that can radiate strong magnetic fields below 30 MHz, such as Industrial, Scientific and Medical (ISM) devices, are also tested for RF interference using a magnetic loop antenna. The corresponding ISM emissions standards are FCC Part 18, EN 55011 and CISPR 11.

The regulatory emission limits of FCC Part 15 and the EU generic emission limits are similar but not identical, as Tables 3. 4 and 5 below indicate. Key differences between the US and EU requirements are:

- The EU radiated emission limits are specified only up to 1 GHz; US limits can extend above 1 GHz, depending on the maximum frequency in the test item. Nevertheless, if a device in the EU can emit interference above 1 GHz, the EMC Directive requires additional testing.
- FCC and EU environment definitions are not identical (see Table 2).
- The EU generic standards specify measurement of telecom port emissions, and EN 61000-6-3 requires flicker and harmonic emissions. FCC Part 15 does not specify these.
- The EU generic standards include the measurement of impulse noise (clicks) more frequent than 5 per minute. These are not measured under FCC Part 15.

measurement	FCC Part 15 Class A	EU EN 61000-6-4 industrial
Radiated emissions @ 10m	30-88 MHz 39 dBµV/m 88-216 MHz 43.5 dBµV/m 216-960 MHz 46.4 dBµV/m Above 960 MHz 49.5 dBµV/m	30-230 MHz 40 dBµV/m 230-1000 MHz 47 dBµV/m
Conducted emissions on ac power port	0.15-0.5 MHz 79 dBµV QP 66 dBµV AV 0.5-30 MHz 73 dBµV QP 60 dBµV AV	0.15-0.5 MHz 79 dBµV QP 66 dBµV AV 0.5-30 MHz 73 dBµV QP 60 dBµV AV
Conducted emissions on telecommunications port	No requirement	0.15-0.5 MHz 97-87 dBµV QP 84-74 dBµV AV 0.5-30 MHz 87 dBµV QP 74 dBµV AV 43 dBµA QP 30 dBµA AV

Table 3 – Comparison of FCC and EU generic industrial emission limits. QP = Quasi-peak detector, AV = Average detector. Radiated emission measurements below 1 GHz use a QP detector.

measurement	FCC Part 15 Class B	EU EN 61000-6-3 residential
Radiated emissions @ 10m	30-88 MHz 29.5 dBµV/m 88-216 MHz 33 dBµV/m 216-960 MHz 35.6 dBµV/m Above 960 MHz 43.5 dBµV/m	30-230 MHz 30 dBµV/m 230-1000 MHz 37 dBµV/m
Conducted emissions on ac power port	0-2 kHz No requirement 0.15-0.5 MHz 66-56 dBµV QP 56-46 dBµV AV 0.5-5 MHz 56 dBµV QP 46 dBµV AV 5-30 MHz 60 dBµV QP 50 dBµV AV	0-2 kHz *rated current ≤ 16A* harmonics IEC 61000-3-2 flicker IEC 61000-3-3 *rated current > 16A* harmonics IEC 61000-3-12 flicker IEC 61000-3-11 0.15-0.5 MHz 66-56 dBµV QP 56-46 dBµV AV 0.5-5 MHz 56 dBµV QP 46 dBµV AV 5-30 MHz 60 dBµV QP 50 dBµV AV

Table 4 – Comparison of FCC and EU generic residential emission limits. QP = Quasi-peak detector, AV = Average detector. Radiated emission measurements below 1 GHz use a QP detector.

measurement	FCC Part 15 Class B	EU EN 61000-6-3 residential
Conducted emissions on dc power port	No requirement	0.15-0.5 MHz 79 dBµV QP 66 dBµV AV 0.5-30 MHz 73 dBµV QP 60 dBµV AV
Conducted emissions on telecommunications port	No requirement	0.15-0.5 MHz 84-74 dBµV QP 74-64 dBµV AV 0.5-30 MHz 74 dBµV QP 64 dBµV AV 30 dBµA QP 20 dBµA AV

Table 5 – EU generic residential emission limits where there is no corresponding FCC Part 15 requirement. QP = Quasi-peak detector, AV = Average detector.

Susceptibility

EN 61000-6-1 (residential, commercial and light industrial environments) and EN 61000-6-2 (industrial environments) apply to all types of power installations and equipment in the EU. In the USA, IEEE 1547 for distributed power resources contains several of the same types of EMC disturbances as the EU standards. Common sources for these disturbances are noted in Table 6, and a comparison of the susceptibility tests is given in Table 7 below.

disturbance	Typical source of disturbance	Test standards
Electrostatic discharge (ESD)	Static buildup on persons	IEC 61000-4-2
Radiated electric field	Broadcast stations, cell phones	IEC 61000-4-3, IEEE C37.90.2
Electric fast transient bursts	Power line switching transients	IEC 61000-4-4
Surge	Lightning-induced power line transient	IEC 61000-4-5, IEEE C62.41.2
RF common mode voltage	Low-frequency radio stations	IEC 61000-4-6
Power line magnetic field	Nearby power line wiring	IEC 61000-4-8
Power line dips and variations	Power line load variations and switching	IEC 61000-4-11
Ring wave	Power line switching and lightning-induced transients	IEC 61000-4-12, IEEE C62.41.2

Table 6 – Common electromagnetic disturbances and their corresponding test standards.

disturbance	reference	Maximum disturbance amplitude in standard below		
		IEEE 1547	EN 61000-6-1 residential	EN 61000-6-2 industrial
Electrostatic discharge (ESD)	IEC 61000-4-2	X	4 kV contact, 8 kV air	4 kV contact, 8 kV air
Radiated electric field	IEC 61000-4-3	X	3 V/m, 80-1000 MHz and 1.4-2.7 GHz, 80% modulated at 1 kHz	10 V/m, 80-1000 MHz, 3 V/m, 1.4-2 GHz, 1 V/m, 2-2.7 GHz, 80% modulated at 1 kHz
	IEEE C37.90.2	20 V/m, 80-1000 MHz, 80% modulated at 1 kHz; 20 V/m at 900 MHz, 200 Hz on-off modulation	X	X
Electric fast transient bursts	IEC 61000-4-4	X	1 kV pulses at 5 kHz	2 kV pulses at 5 kHz
Surge	IEC 61000-4-5	X	2 kV, 1.2 x 50 µs	2 kV, 1.2 x 50 µs
	IEEE C62.41.2	6 kV, 1.2 x 50 µs	X	X
RF common mode voltage	IEC 61000-4-6	X	3 V, 0.15-80 MHz, 80% modulated at 1 kHz	10 V, 0.15-47, 68-80 MHz; 3 V/m, 47-68 MHz, 80% modulated at 1 kHz
Power line magnetic field	IEC 61000-4-8	X	3 A/m	30 A/m
Power line dips and dropouts	IEC 61000-4-11	X	100% dip for 0.5, 1 cycle; 30% dip for 25/30 cycles; dropout for 250/300 cycles	100% dip for 1 cycle; 30% dip for 25/30 cycles; 60% dip for 10/12 cycles; dropout for 250/300 cycles
Ring wave	IEC 61000-4-12	X	X	X (2.5 kV at 1 MHz in IEC TS 61000-6-5 for power stations)
	IEEE C62.41.2	6 kV at 100 kHz	X	X

Table 7 – Comparison of susceptibility or immunity tests for US grid-connected distributed power systems (IEEE 1547) and EU generic EMC standards which apply to both grid-connected and independent power equipment.

The testing specified in Table 7 under IEEE 1547 bears no relationship to any FCC EMC requirements; these are given in Tables 3 and 4. Rather, IEEE 1547 is requisite for product safety listing or certification under UL 1741 (covering inverters, converters, controllers and interconnection system equipment for use with distributed energy resources). By contrast, the generic EU EMC requirements EN

61000-6-1, -2, -3 and -4 are harmonized to the EMC Directive and compliance provides a regulatory presumption of conformity. The EU harmonized safety standard corresponding approximately to UL 1741 is EN 50178.

Powerline communications

In addition to the unintentional electromagnetic disturbances on ac power lines noted in Table 6, electric utility companies have for decades superimposed low-frequency signals on their medium voltage (~ 10-40 kV) and low voltage (< 1 kV)distribution lines for network monitoring and control. More recently, both utilities and subscribers are using power lines at high frequencies for Internet communications. These added signals may not be anticipated by common conducted susceptibility standards, so the grid-connected renewable resource equipment vendor needs to confirm functionality for these signals - whether or not the technology is being employed internally.

Low-frequency signaling over power lines by power utilities has long been permitted in both the USA and EU. In the USA, such power line communications (or PLC) are regulated on a non-interference basis by the FCC under Part 15, section 15.113. The span may not include the subscriber or house wiring. The available operating frequency band is 9 – 490 kHz. In the EU, the available frequency band is 3 – 95 kHz and the corresponding harmonized EMC standards are:

EN 50065-1 Signaling on low-voltage electrical installations in the frequency range 3 kHz to 148.5 kHz - Part 1: General requirements, frequency bands and electromagnetic disturbances. The maximum applied voltage limit is 134 dBµV or 5 V. The emission limits above 150 kHz are identical to those in EN 61000-6-3 (Table 4).

EN 50065-2-3 Signaling on low-voltage electrical installations in the frequency range 3 kHz to 148.5 kHz -- Part 2-3: Immunity requirements for mains communications equipment and systems operating in the range of frequencies 3 kHz to 95 kHz and intended for use by electricity suppliers and distributors. The immunity test levels are similar to those in EN 61000-6-3 (Table 7), except that the magnetic immunity test level increases to 100 A/m.

There are also harmonized susceptibility test standards for non-utility signaling over power lines: EN 50065-2-1 (residential, commercial and light industrial environments) and EN 50065-2-2 (industrial environments). These parallel the generic standards shown in Table 7.

More recently, high-frequency signaling has been permitted over both utility distribution lines and domestic power wiring. The FCC rules governing RF emissions from utility-controlled medium-voltage (MV) and low-voltage (LV) lines are found in FCC Part 15 Subpart G for "Access Broadband over Power Line" or Access BPL, in the frequency band 1.705 – 80 MHz. The FCC limits address radiated emissions only, and use Part 15 Class A limits for MV systems and Part 15 Class B for LV systems. There are no FCC equipment susceptibility requirements.

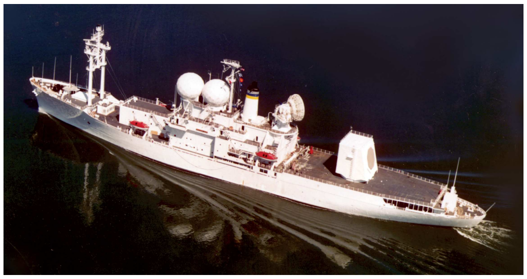
Acceptance of high-frequency or broadband over powerline communications in the EU has been impeded by the absence of any harmonized emissions standards that allow practical system operation. Emissions standards such as EN 55022, EN 61000-6-3 and -4 contain ac conducted limits that are too low to be useful. Nevertheless, a harmonized immunity standard has been published:

EN 50412-2-1 Power line communication apparatus and systems used in low-voltage installations in the frequency range 1.6 MHz to 30 MHz -- Part 2-1: Residential, commercial and industrial environment - Immunity requirements

The susceptibility or immunity levels required in this standard agree with the levels shown in Table 7 for both residential and industrial environments.

In the USA, grid-connected renewable power systems such as distributed PV or wind power should target compliance with the most stringent combination of IEEE 1547 and EU generic EMC standards for the intended environment. The equipment should provide adequate filtering against any powerline carrier signals that may be in use, or – if the system is intended to respond to such signals - carefully route the signals only to intended receivers. If the renewable power system generates powerline carrier signals, self-compatibility must be assured.

Wireless communications



Product EMC standards such as EN/IEC 60947-1 (low-voltage switchgear and controlgear) and EN/IEC 61326-1 (process control and measurement) provide generally adequate RF immunity from common radio transmitters as AM/FM/TV broadcast, cell phones, walkie-talkies and remote controls. Similarly, renewable resource systems comprising a number of different equipment types and evaluated to the requirements of the generic EMC standards EN/IEC 61000-6-1 and -2 will afford protection from performance degradation in the presence of most common RF interference sources.

Additional EMC considerations may come into play when either the operating environment of the renewable power system or specific equipment configurations result in RF fields higher than those in the relevant EMC standards. For example:

The system is deployed in a navigable waterway and may be exposed to shipboard radar (> 1 GHz) or low-frequency radio communications fields (0.1 – 27.5 MHz);

The power system contains a radio telemetry or voice communications transmitter antenna in close proximity to other electronics;

Operating and maintenance personnel are using handheld two-way radios while working in open cabinet enclosures.

In each of these cases the potential maximum RF field should be compared with the tested immunity limits of the power system and its electronic components.

Summary

Renewable resource power systems contain the promise of environmental friendliness and petrochemical independence. In many parts of the world, such power systems are being encouraged by tax incentives and simplified regulation.

Each type of resource considered here – biomass, geothermal, hydroelectric, photovoltaic, tidal, wave and wind – has its own advantages and drawbacks. Some, such as PV and wind, are well-suited to residential or distributed configurations. All, even the largest utility-grade power systems, are subject to EMC considerations for the sake of either regulatory compliance, reliable operation, or both.

EMC regulations for renewable resource power systems vary widely around the world, but the US FCC and EU EMC regulations are fairly representative so they are examined here. The FCC does not generally regulate susceptibility or immunity of electronic equipment, but for grid-connected resources in the USA immunity is necessary for product safety listing or certification. In the EU, both grid-connected and independent power systems must meet EMC criteria.

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Intertek Commercial & Electrical Services specialize in testing and certification for a wide range of products, including household appliances, electronics, automotive components, heating equipment and air conditioning, cable and wiring accessories, industrial machinery, medical equipment, lighting, semiconductors and manufacturing products for construction. We provide industry-specific certification services for electromagnetic (EMC) compatibility and specialized telecommunications.