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ENVIRONMENTAL STANDARDS AND POWER QUALITY EVALUATION

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ENVIRONMENTAL STANDARDS AND POWER QUALITY EVALUATION

By

Dr. Ibrahim El-Mohr
Regional Advisor in Energy
UN-ESCWA

ENVIRONMENTAL STANDARDS AND POWER QUALITY EVALUATION

I. Introduction

1. Electric power systems in ESCWA region and Emissions
2. Transmission Lines Effects.
3. Standard Limits of Electric and Magnetic Fields.

II. Power Quality Standards

1. The changes of customer loads
2. The understanding of power quality problems
3. The role of standards
4. The International Electro-technical Commission Standards (IEC)
5. Power system performance standards
6. Power quality terms and definitions
7. Categories and typical characteristics of power system electro-magnetic phenomena

III. International Standards

1. ISO 14000
2. The design for Environment (DfE)

IV. Conclusions and recommendations

ENVIRONMENTAL STANDARDS AND POWER QUALITY EVALUATION

I. INTRODUCTION

1. Electric Power Systems in ESCWA region and Emissions.

Sustainable development of a society depends on the availability of energy resources and on how efficiently they are utilized. Secure reliable supply of electricity with minimum cost to different sectors of the Arab economy is the main concern of electricity and energy authorities. To fulfill this target, a strategy has been set since the beginning of the eighties, focusing on energy efficiency, institutional restructuring of the power sector, enhancing the utilization of new and renewable resources, localization of electrical equipment and electric interconnection with neighboring countries. The main sources of electrical energy generation are hydro, natural gas and oil. The electricity sector in the ESCWA region has developed tremendously during the last 25 years to serve the development plans in the region. In 1975 the installed power plants capacity was 9585 MW and increased rapidly at 16% during the period 1975-1985 to reach 42172 MW, 4.4 times of 1975 capacity coping with the high economic development rates which characterized such period. However, the growth rate of the installed capacity has declined after 1985 to 1997 to reach 4.1 only to reach 68239 MW (1.62 times that of 1985 and 7.12 that of 1975) with an average growth rate of 9.3% during the period 1975-1997.

Improving power system efficiency involves both the supply side as well as the demand side. On the supply side, this includes the maximum use of all available hydro energy and natural gas resources (thus reducing the gaseous emissions and saving fuel oil for exportation), increasing the efficiency of power plants by rehabilitation of old ones and conversion of the open cycle gas turbines to combined cycle.

These actions led to the reduction of the average rate of fuel consumption from 320 gm/KWh in 1985 to 240 gm/KWh in 1995, resulting in considerable accumulated savings in fuel consumption.

Today power system interconnections are spreading all over the world, and it will be a reality in ESCWA region very soon, bringing economical as well as technical benefits to the countries involved. One of the main advantages of the interconnection in Arab region is to decrease the total reserve capacity required to meet equipment forced outages, and the cutting down of the capital investments necessary to install additional generating plants which in turn will reduce the gaseous emissions, also the interconnection of power systems will allow the use of larger generating units of higher efficiency, thus reducing CO_2 emission.

The interconnections for electric power transmission are subject to environmental assessment to meet requirements of the respective national

governments and international investors. An initial environmental assessment is required to outline the issues to be addressed as required by regulatory agencies and investors. Technical assurances, risks, and anticipated returns on investment are traditionally dealt with in a feasibility study. Environmental and sociocultural impacts must also be included.
The most important factor in the environmental task is the reduction of CO_2 emission. In this aspect, power plants play an essential role. Development in the last decade made it possible to reduce the CO2 emission for fossil power generation. In addition, a considerable portion of new generation has shifted from coal-fired generation to oil and natural gas, which produce a lower amount of CO_2 emission.

2. Transmission Lines Effects

The development of the power system and extension of transmission lines must be assimilated with the environment. Now, a compromise has generally been considered between the cost on one hand and the environmental impact, in addition to the quality and safety on the other hand.
The environmental impact of transmission lines may be divided into the following three terms:

- **ECOLOGY:** The ecological impact reflects the influence on the vegetation and fauna when the transmission line is constructed or is being operated or maintained. The passage of lines in forest regions demands right-of-way clearance. Continuous trimming of trees in forests and cultivated areas would be necessary.
- **AESTHETICS:** Aesthetic impact reflects the effects of lines and electrical installation on the charm of the scenery of the landscape whether mountainous or greenery.
- **ELECTRICAL SYSTEM PHENOMENA:** Electrical, magnetic, electromagnetic, and acoustic impacts result from the inherent phenomena of the electric system. Acoustic impact results from corona discharges on high-voltage transmission line conductors and from transformer noise. Electric and magnetic fields of the lines induce potentials and currents in nearby conducting material. Power lines and installations are generally outside cities, and human exposure is rather remote. Corona discharge and other discharges produce high-frequency electromagnetic radiation, influencing radio and television reception. All of these, however, decay quickly with the distance from the transmission lines.

3. Standard Limits of Electric and Magnetic Fields.

The electromagnetic field issue remains a major issue for both the transporters and the customers.
Usually there are no international standards for the limits of electric and magnetic fields produced by transmission lines at the edge of the right-of-

way. Some countries have set their own regulations for the electric and magnetic field limits, and some other countries have no set limits.
The World Health Organization (WHO) stated that up to a current density of 10 ma/m2 induced by magnetic fields, only minor biological effects have been reported. This factor formed the basis for the International Radiation Protection Association (IRPA) guidelines.

II. POWER QUALITY STANDARDS

The term "power quality" is applied to a wide variety of electromagnetic phenomena on the power system. The increasing application of electronic equipment has heightened the interest in power quality in recent years and this has been accompanied by the development of a special terminology to describe the phenomena.

Power quality has always been important. However, for many years, the equation defining power quality was very simple:

POWER QUALITY = RELIABILITY

Two major changes in the characteristics of customer loads and systems have completely changed the nature of the power quality equation:

1. <u>The change of customer loads</u>:

Customer loads were linear in nature, and they fell into the categories of lighting, heating and motors.

Two major changes in the characteristics of customer loads and systems have completely changed the nature of the power quality equation:

(i) <u>The sensitivity of the loads themselves</u>: The devices and equipment being applied in industrial and commercial facilities are more sensitive to power quality variations than equipment applied in the past. New equipment includes microprocessor-based controls and power electronics devices that are sensitive to many types of disturbances besides actual interruptions. Controls can be affected by momentary voltage sags or relatively minor transient voltages, resulting in nuisance tripping or mis-operation of an important process;

(ii) <u>The fact that these sensitive loads are interconnected in extensive networks and automated processes</u>. This makes the whole system as sensitive as the most sensitive device and increases the problem by requiring a good zero potential ground reference for the entire system.

These changes in the load characteristics have created a growing market for power conditioning equipment that can protect the loads from the wide variety of power quality variations that can cause problems. The power quality problems don't always come from the utility system either.

Most of the transient voltages in a facility are caused by switching operations within the facility. Wiring and grounding problems increase susceptibility to problems. Power electronics equipment, such as adjustable speed drives, result in a continuous string of transients (notching) as well as steady state harmonic distortion that can cause heating in other loads within the facility.

2. The understanding of power quality problems:

Understanding the problems associated with power quality variations is the first step towards developing standards and the optimum approach to solutions. Understanding means being able to relate the causes of power quality variations to impacts on equipment and processes within customer facilities. This requires an understanding of the utility power system, the customer electrical system, and the equipment characteristics.

Three investigations are important to improve the understanding of power system quality problems:

(a) Monitoring: Utilities and customers are both doing more and more monitoring of power quality. This monitoring is being performed on the power system and within customer facilities:

(b) Case studies: Case studies are a way of characterizing power quality concerns for individual customers and systems. When the results of all these case studies are shared and combined, the results illustrate important general characteristics of power quality concerns for different kinds of customers and equipment. The solutions implemented in particular case studies can be patterns for more general solutions to power quality problems;

(c) Analytical tools. The results of monitoring efforts and case studies are being used to improve analytical models for simulating system disturbances. The advantage of the simulation approach is that it allows evaluations of systems and conditions that may not yet actually exist (future expansion plans, for example).

3. The role of standards:

Power quality problems ultimately impact the end-user. However, there are many other parties involved in creating, propagating and solving power quality problems. Power quality standards must provide guidelines, recommendations and limits to help assure compatibility between end use equipment and the system where it is applied. The standards affect all of the parties shown in figure (1). There is active interest in the world to establish power quality standards to deal with these problems.

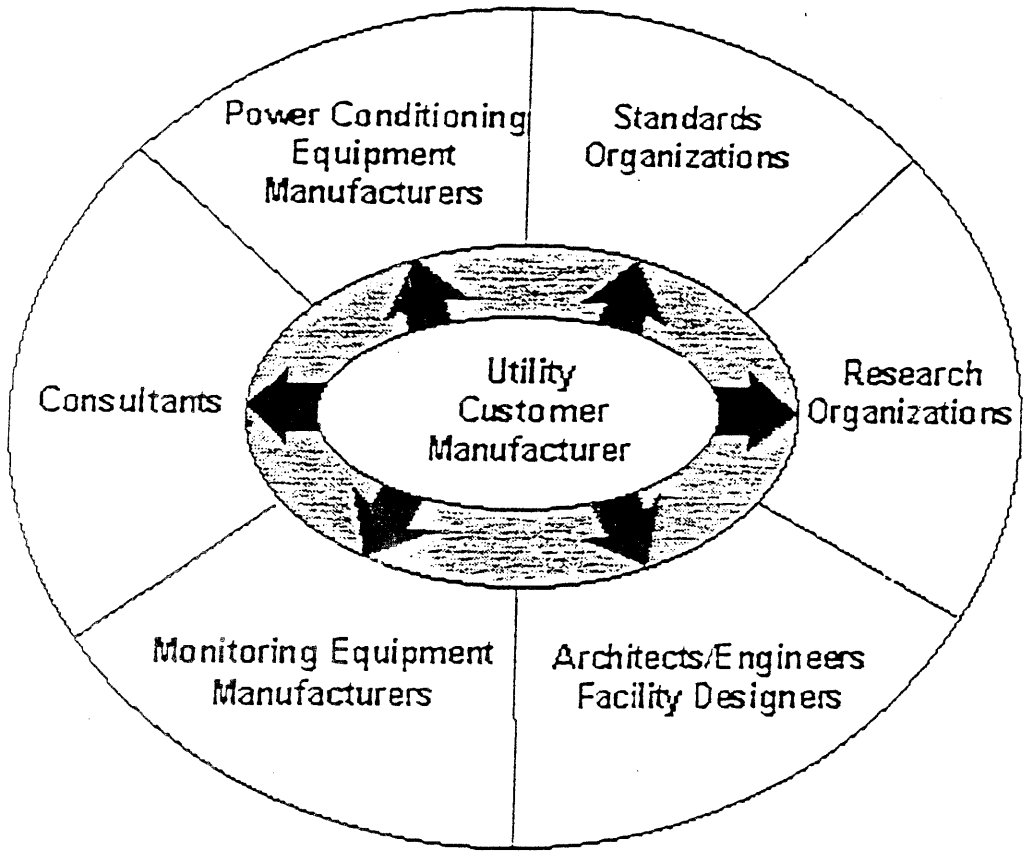

Figure (1): Players that influence End-use Power Quality

International organizations are developing new standards to deal with the increased concern for system power quality levels. The International Electrotechnical Commission (IEC), based in Geneva, Switzerland, composed of about 50 national committees representing industrial countries throughout the world. The IEC promotes international cooperation in matters related to electrical engineering standards.

Among the international congresses reporting to IEC are two that produce technical reports on electric power. One is the International Conference on Large High-Voltage Networks (Cigre). The other is the International Congress on Electrical Distribution Networks (Cired). These groups' work feeds directly into standards the IEC approves, including some with sections devoted to power quality, such as IEC 1000-2-1, electromagnetic compatibility (EMC).

The EMC standards deal with power quality issues. The term Electromagnetic Compatibility includes concerns for both radiated and conducted interference with end use equipment (Figure 2).

4. The International Electrotechnical Commission (IEC) standards:

The IEC standards fall into the following six categories:

(i) General: These provide definitions, terminology, ... etc. (IEC 1000-1-x);
(ii) Environment: Characteristics of the environment where equipment will be applied (IEC 1000-2-x);
(iii) Limits: Emission limits define the allowable levels of disturbances that can be caused by equipment connected to the power system (IEC 1000-3-x).

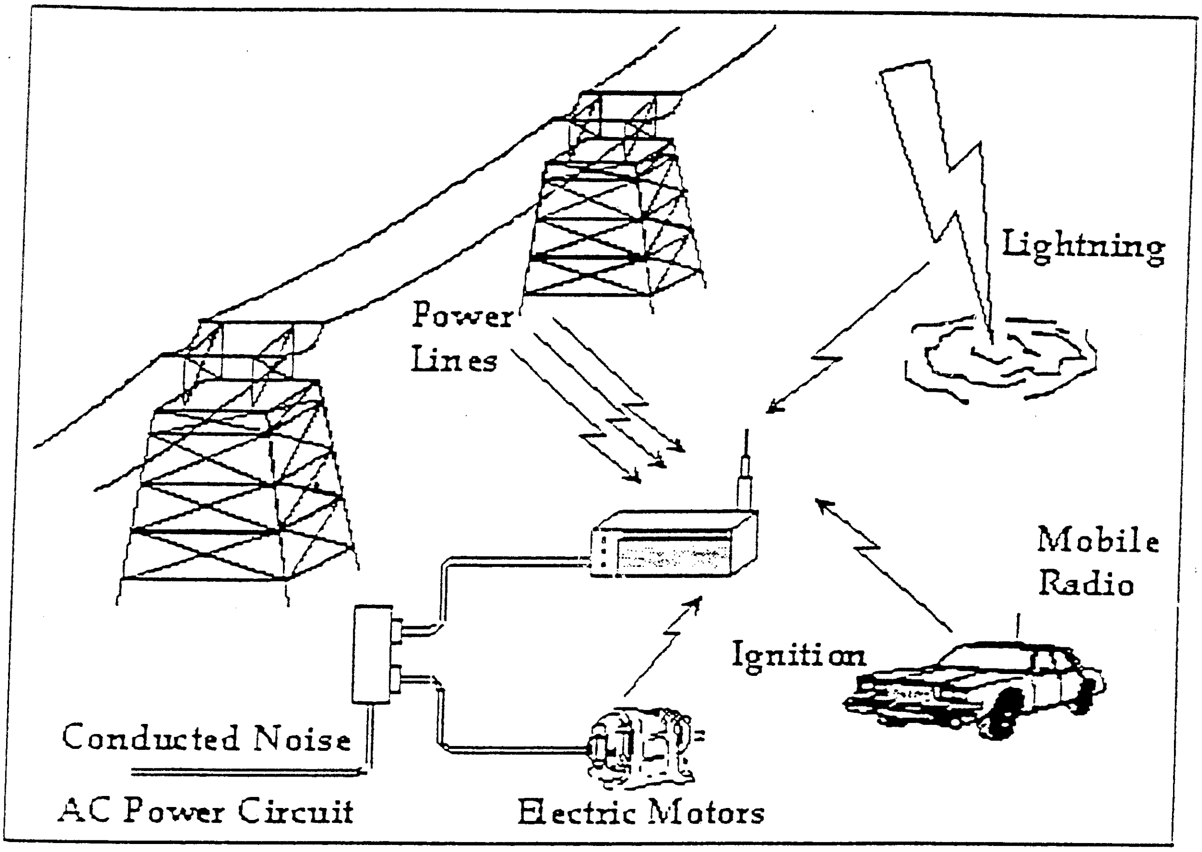

Figure (2): Some factors affecting Electromagnetic Compatibility

(iv) Testing and Measurement Techniques: These provide detailed guidelines for measurement equipment and test procedures to assure compliance with the other parts of standards (IEC 1000-4-x);

(v) Installation and Mitigation Guidelines: These are designed to provide guidance in application of equipment, such as filters, power conditioning equipment, surge suppressors, ... etc., to solve power quality problems (IEC 1000-5-x);

(vi) Generic and Product Standards: These will define immunity levels required for equipment in general categories or for specific types of equipment (IEC 1000-6-x).

These IEC standards are adopted generally by the European Community and become requirements for equipment sold in Europe. Their application in the rest of the world varies and very few of them are adopted outright in the United States.

The IEEE is heavily involved in developing power quality standards and has recently been working more closely with other international organizations to reduce overlap. These groups are working on standards that address power quality levels from both ends, by requiring that emissions from customers' loads be limited and by establishing benchmarks of quality for utilities.

5. Power system performance standards:

Customers and manufacturers need these standards to define the environment that in which their equipment is expected to work. These performance standards should include at least:

* Interruptions (including momentary)
* Voltage sags
* Steady state voltage regulation
* Voltage unbalance (negative sequence)
* Harmonic distortion in the voltage
* Transient voltages.

The equipment manufacturers must be able to provide information describing the sensitivity of their equipment to these variations. With information on typical system performance based on historical and calculated data along with information on equipment sensitivity, customers will be able to perform economic evaluations of power conditioning alternatives.

The overall focus needs to be on economics using a systems approach (Figure 3). We need to develop tools that can help find the optimum system design including power conditioning for sensitive equipment. The alternatives should include improved immunity at the equipment level, power conditioning at

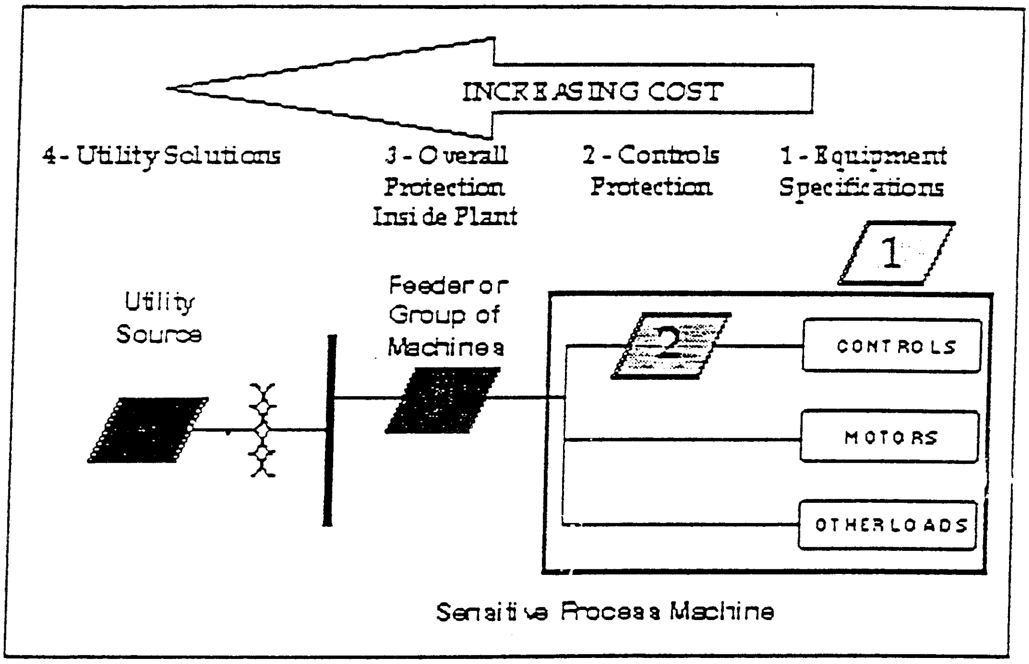

Figure (3): Economic evaluation of alternative for Power Quality Improvement the equipment level, power conditioning at more centralized locations within the customer system, and measures to improve performance on the utility system.

6. Power quality terms and definitions:

The terminology presented here reflects the international efforts to standardize definitions of power quality terms. The following table shows the categorization of electromagnetic phenomena used for the power quality community. The table provides information regarding typical spectral content, duration, and magnitude where appropriate for each category of electromagnetic phenomena. The categories of the table provide a means to clearly describe an electromagnetic disturbance. The categories and their descriptions are important in order to be able to classify measurement results and to describe electromagnetic phenomena that can cause power quality problems.

7. Categories and typical characteristics of power system electromagnetic phenomena:

(a) Transients: The term "Transients" has long been used in the analysis of power system variations to denote an event that is undesirable but momentary in nature. Another word in common usage that is often considered synonymous with transient is "surge". Broadly speaking, transients can be classified into two categories:
- (i) Impulsive transient;
- (iii) Oscillatory transient.

(b) Short duration voltage variations: This category encompasses the IEC category of "voltage dips and short interruptions". Each type of variation can be designated as instantaneous, momentary, or temporary, depending on its duration as defined in the table. The short duration voltage variations are caused by fault conditions, the energization of large loads (high starting currents), or intermittent loose connections in power wiring. Depending on the fault location and the system conditions, the fault can cause:
- (i) Sags (temporary voltage drops);
- (ii) Swells (voltage rises);
- (iii) Interruptions (complete loss of voltage).

(c) Long duration voltage variations: Long duration variations encompass rms deviations at power frequencies for longer than one minute. Long duration variations can be:
- (i) Sustained interruptions;
- (ii) Under voltages;
- (iii) Over voltages.

(d) Voltage imbalance: It is defined as the maximum deviation from the average of the three-phase voltages or currents, divided by the average of the three-phase voltages or currents, expressed in percent, or can be defined using symmetrical components;

Categories and Typical Characteristics of Power System Electromagnetic Phenomena

Categories	Typical Spectral Content	Typical Duration	Typical Voltage Magnitude
1.0 Transients			
1.1 **Impulsive**			
1.1.1 Nanosecond	5 ns rise	< 50 ns	
1.1.2 Microsecond	1 μs rise	50 ns -1ms	
1.1.3 Millisecond	0.1 ms rise	> 1 ms	
1.2 **Oscillatory**			
1.2.1 Low Frequency	< 5 kHz	3 - 50 ms	0 - 4 pu
1.2.2 Medium Frequency	5 - 500 kHz	20 μs	0 - 8 pu
1.2.3 High Frequency	0.5 - MHz	5 μs	0 - 4 pu
2.0 Short Duration Variations			
2.1 **Instantaneous**			
2.1.1. Sag		0.5 - 30 cycles	0.1 - 0.9 pu
2.1.2 Swell		0.5 - 30 cycles	1.1 - 1.8 pu
2.2 **Momentary**			
2.2.1 Interruption		0.5 cycles - 3 s	< 0.1 pu
2.2.2 Sag		30 cycles - 3 s	0.1 - 0.9pu
2.2.3 Swell		30 cycles - 3 s	1.1 - 1.4 pu
2.3 **Temporary**			
2.3.1 Interruption		3 s - 1min	< 0.1 pu
2.3.2 Sag		3 s - 1min	0.1 - 0.9 pu
2.3.3 Swell		3 s - 1min	1.1 - 1.2 pu
3.0 Long Duration Variations			
3.1 Interruption, Sustained		> 1 minute	0.0 pu
3.2 Undervoltages		> 1 minute	0.8 - 0.9 pu
3.3 Overvoltages		> 1 minute	1.1 - 1.2 pu
4.0 Voltage Imbalance		steady state	0.5 - 2%
5.0 Waveform Distortion			
5.1 DC Offset		steady state	0 - 0.1%
5.2 Harmonics	0 - 100^{th} H	steady state	0 - 20%
5.3 Inter-harmonics	0 - 6 kHz	steady state	0 - 2%
5.4 Notching		steady state	
5.5 Noise	broad-band	steady state	0 - 1%
6.0 Voltage Fluctuations	< 25 Hz	intermittent	0.1 - 7%
7.0 Power Frequency Variations		< 10s	

(e) Wave form distortion: It is defined as a steady state deviation from an ideal sine wave of power frequency principally characterized by the spectral content of the deviation. There are five primary types of wave form distortion:

(i) DC offset;
(ii) Harmonics;
(ii) Interharmonics;
(iv) Notching;
(iv) Noise.

(f) Voltage fluctuations (voltage flicker): Voltage fluctuations are systematic variations of the voltage envelop or a series of random voltage changes, the magnitude of which does not normally exceed the voltage ranges specified by IEC 555-3 of 0.9 pu to 1.1 pu;

(g) Power frequency variations: Power frequency variations are defined as the deviation of the power system fundamental frequency from it specified nominal value (e.g. 50 Hz or 60 Hz).

III. INTERNATIONAL STANDARDS

1. The ISO 14000:

What may spur that cultural change at many companies could be a desire for certification under the new ISO 14000 family of International environmental standards. The ISO 14001 voluntary standards for environmental management could turn into a fact of international standards, such that any company that wishes to do business internationally will have to obtain certification.

ISO 14001 standards are descriptive, rather than prescriptive. Companies must establish an environmental policy, identify key issues, adopt training and documentation procedures, and constantly reduce waste and generally improve. The Design-for-environment (DfE) fits in nicely with the continuous improvement and waste reduction concepts.

Many hope that in time, these international standards will benefit multinationals by enabling them to conform to a single set of practices worldwide. At present, they must comply with as many sets of environmental regulations as there are countries hosting their facilities.

Organizations need to break away from the formal techniques that attempted to extrapolate alternative futures from environmental trends. Systematic change is needed in how industry and environmental managers think about the use of materials, production processes, and product formulation, use, and disposal. Success requires integrating environmental issues into all phases of the operation and the development of environmental indicators that are part of the business strategy. Envisioning how to do this is easy, but changing the political, technical, and cultural forces that define the strategic business development process is not.

2. The Design for Environment:

The Design for the Environment (DfE) has not fully been accepted within organizations. Even within those that developed DfE programmes, the challenge remains how to alter the understanding and cultures within them. It is not enough to make better individual decisions on an individual process or product. We need to develop better decision-making processes that systematically integrate environmental considerations into the product design process. This is the value of environmental management systems; they shift the focus from individual decisions to the decision-making process.

IV. CONCLUSIONS AND RECOMMENDATIONS

1. Systematic procedures for evaluating power quality concerns can be developed but they must include all levels of the system, from the generation, transmission system to the end-user facilities. Power quality problems show up as impacts within the end-user facility but may involve interaction between all levels of the system.

2. A consistent set of definitions for different types of power quality variations is the starting point for developing evaluation procedures. The definitions permit standardized measurements and evaluations across different systems.

3. The end result of each power quality evaluation will be an economic analysis. This must involve the end-user in identifying the economic impact of power quality variations on the affected process or equipment. Then economic evaluations can be performed to evaluate solutions at different levels of the system.

4. The End-use Equipment must become less sensitive to power quality variations. As we understand the economics involved, the immunity characteristics of the equipment will become part of the purchase decision making process. When this happens, manufacturers will consider it important enough to improve the immunity. In the long run, the most economical place to solve most power quality problems will be in the end-use equipment itself.