WIND GENERATOR REACTIVE POWER COMPENSATION WITH MICROCONTROLLER SOLUTION

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Abstract: Power factor is a measurement of how efficiently a facility uses electrical energy. A high power factor means that electrical capacity is being utilized effectively, while a low power factor indicates poor utilization of electric power. However, this is not to be confused with energy efficiency or conservation that applies only to energy. Improving the efficiency of electrical equipment reduces energy consumption, but does not necessarily improve the power factor.
The paper presents a microcontroller power factor compensation for wind energy generator. The main aspects of the power factor compensation with capacitors are discussed and the microcontroller solution is presented.

Keywords: power factor, capacitor, active power, reactive power, microcontroller, compensation,

1. INTRODUCTION

For power factor compensation first the collecting data is necessary. The data collected was compiled into a report that confirmed wind generator power factor and other power system data. It also identified the capacitor bank size and other specifications to meet the compensation needs.

Power factor involves the relationship between these two types of power. Active Power is measured in kilowatts (kW) and Reactive Power is measured in kilovolt-amperes-reactive (kVAr). Active power and reactive power together make up Apparent Power, which is measured in kilovolt-amperes (kVA).

Power factor is the ratio between active power and apparent power. Active power does work and reactive power produces an electromagnetic field for inductive loads.

Lightly-loaded or varying-load inductive equipment such as arc furnaces, molding equipment, presses, etc., are all examples of equipment that can have a poor power factor. One of the worst offenders is a lightly loaded induction motor (e.g., saws, conveyors, compressors, grinders, etc.).

End users should be concerned about low power factor because it means that they are using a facility's electrical system capacity inefficiently. It can cause equipment overloads; low voltage conditions, greater line losses, and increased heating of equipment that can shorten service life. Most importantly, low power factor can increase an electric bill with higher total demand charges and cost per kWh.

The studies show that the automat power compensation it is recommended.

For automatization of power factor compensation a PIC 16F84A microcontroller is used. This ordinary microcontroller allow a very good compensation with the capacitor bank.

2. CORRECTING POOR POWER FACTOR

Adding power factor correction capacitors to a facility's electrical distribution system generally solves low power factor. Power factor correction capacitors supply the necessary reactive portion of power (kVAr) for inductive devices. By supplying its own source of reactive power, a facility frees the utility from having to supply it. This generally results in a reduction in total customer demand and energy charges.

Power factor correction requirements determine the total amount of capacitors required at low voltage buses. These capacitors can be configured as harmonic filters if necessary. The power factor characteristics of plant loads typically are determined from billing information, however, in the case of a new installation, typical load power factors will determine the required compensation.

A properly designed capacitor application should not have an adverse affect on end user equipment or power quality. However, despite the significant benefits that can be realized using power factor correction capacitors, there are a number of power quality-related concerns that should be considered before capacitors are installed. Potential problems include increased harmonic distortion and transient overvoltages.

Harmonic Distortion: Harmonic distortion on power systems can most simply be described as noise that distorts the sinusoidal waveshape. Nonlinear loads cause harmonics (e.g., adjustable-speed drives, compact fluorescent lighting, induction furnaces, etc.) connected to a facility's power system. These loads draw nonsinusoidal currents (e.g., on a 50 Hz system, the 6th harmonic is equal to 300 Hz), which in turn react with the system impedance to produce voltage distortion. Generally, the harmonic impedances are low enough that excessive distortion levels do not occur. However, power factor correction capacitors can significantly alter this impedance and create what is known as a "resonance" condition. High voltage distortion can occur if the resonant frequency is near one of the harmonic currents produced by the nonlinear loads. Indications that a harmonic resonance exists include device overheating, frequent circuit breaker tripping, unexplained fuse operation, capacitor failures, and electronic equipment malfunction. Ways to avoid excessive distortion levels include altering (or moving) the capacitor size to avoid a harmful resonance point (e.g., 5th, 7th), altering the size (or moving) of the nonlinear load(s), or adding reactors to the power factor correction capacitors to configure them as harmonic filters.

Transient Overvoltages: Transient overvoltages can be caused by a number of powers systems switching events; however, utility capacitor switching often receives special attention due to the impact on customer equipment. Each time a utility switches a capacitor bank a transient overvoltage occurs. An example of this type of transient is illustrated in the figure below. Generally, these overvoltages are low enough that they do not affect the system. However, high overvoltages can occur when customers have power factor correction capacitors. This phenomenon is often referred to as "voltage magnification". Magnification occurs when the transient oscillation initiated by the utility capacitor switching excites a resonance formed by a step-down transformer and low voltage power factor correction capacitors. Magnified overvoltages can be quite severe and the energy associated with these events can be damaging to power electronic equipment and surge protective devices (e.g., transient voltage surge suppressors). Adjustable-speed drives have been found to be especially susceptible to these transients and nuisance tripping can result even when overvoltage levels are not severe.

3. THE PRINCIPLE OF THE POWER FACTOR COMPENSATION

While the ideal power factor is unity or 1, most industrial loads have a power factor lower than 1. Moreover, this lower power factor is usually inductive, arising out of the windings of transformers, motors, and the like. These loads consume kVARs (the wattless component) from the supply line.

The principle of power factor compensation is to supply these kVARs via a capacitor located close to the load, reducing the current drawn from the supply line.

For an Industry with dynamically changing loads, automatic power factor compensation affords the best return on investment, since the kVAR investment required be smaller than with fixed capacitors needed to meet the entire load.

Automatic power factor correction also avoids leading power factor situations by switching off extra capacitors.

The key operating conditions to be considered are the peaks of:

- Current. Especially due to Inrush and Harmonic Current and
- Voltage

The astute reader would notice:

- The microcontroller is the Brain of the system
- The microcontroller must provide the intelligence to protect the equipment. I.e., brain rather than brawn. Safety alarms and tripping, a critical necessity, is enabled by the fact that it is the average power factor for the month that needs to be maintained. Instantaneous power need not be maintained during abnormalities.
- This is the ONLY way to minimize the cost of the complete panel. Without well-designed protection facilities in the microcontroller the alternative, of over-sizing or over-rating the components to meet the exigencies at site, is far more costly.

4. THE AUTOMATIC POWER FACTOR COMPENSATION

The automatic power factor compensation is build with the PIC 16F84A microcontroller. This microcontroller has a high performance RISC CPU, multiple peripheral features, special microcontroller features such as: 10,000 erase/write cycles Enhanced FLASH, program memory typical, 10,000,000 typical erase/write cycles EEPROM, EEPROM Data Retention > 40 years, in-circuit Serial Programming™ (ICSP™) - via two pins, power-on Reset

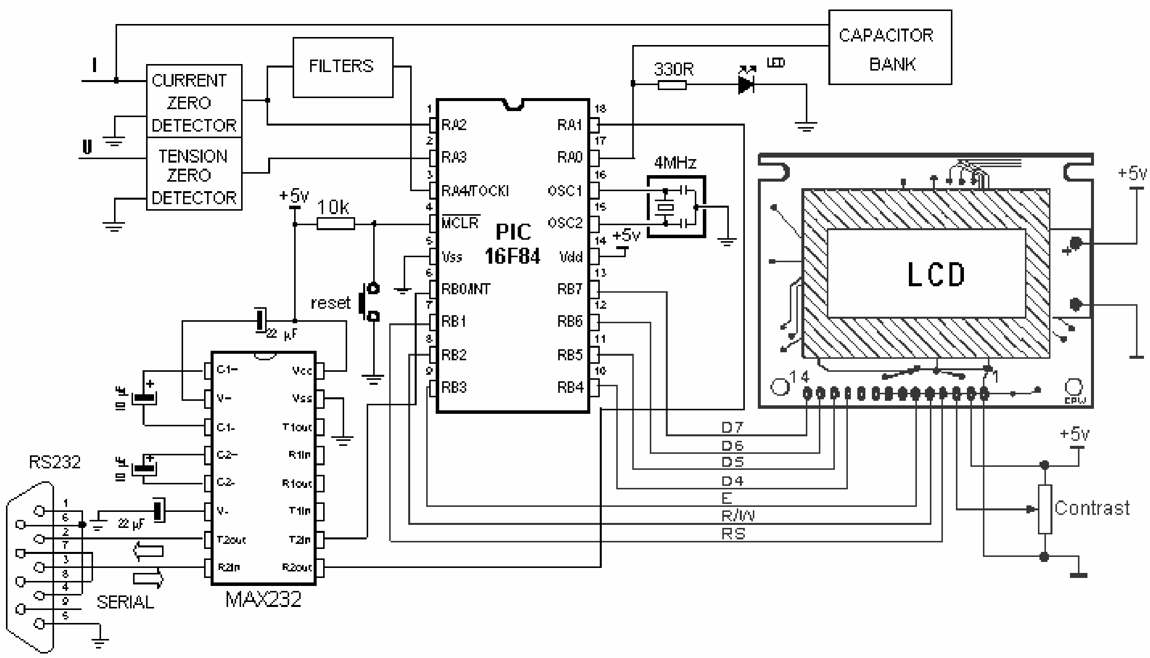

Figure 1. The power factor compensation with PIC 16F84A microcontroller.

(POR), power-up Timer (PWRT), Oscillator Start-up Timer (OST), Watchdog Timer (WDT) with its own On-Chip RC, Oscillator for reliable operation, Code protection, Power saving SLEEP mode.

The circuit block diagram is presented in figure 1.

The components structure of figure 1 block diagram contain the PIC 16F84 microcontroller, current and tension zero detector, filters, filters, capacitor bank, serial communication and LCD display. This structure had shown in figure 1 not include the supply circuitry.

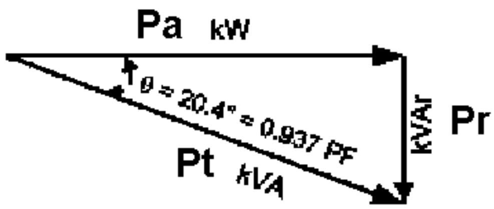

Figure 2. Power Factor (PF) measurement.

The function of the block of filters is to signalize the presence of dangerous harmonics.

Capacitors present lower impedance to higher frequencies. Capacitors thus tend to amplify harmonic current drawn and/or supplied via a distorted voltage supply waveform. Sometimes this calls for special design such as oversized components. Harmonics cause capacitor overload and over-heating through higher circulating currents.
Examples of loads that can distort the supply voltage:

- Switching Power supplies (e.g. UPS, software companies),
- Rectifier converters (e.g. Chlor alkali industry),
- Variable speed variable frequency drives.

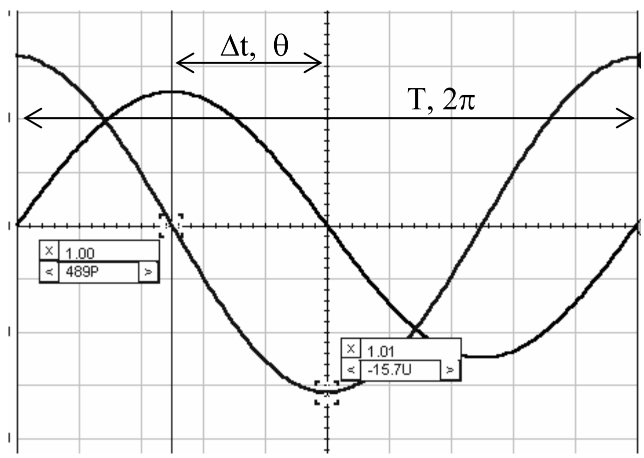

Figure 3. Illustration of the phase difference determination principle.

Very often, the Inrush-current-withstanding ability of a Capacitor is not specified. Typically, one should expect this to be 100 In.

The function of zero current and zero tension blocks is to determine the value of the power factor.

Power factor involves the relationship between two types of power. Active Power is measured in kilowatts (kW) and Reactive Power is measured in kilovolt-amperes-reactive (kVAr). Active power and reactive power together make up Apparent Power, which is measured in kilovolt-amperes (kVA). This relationship is often illustrated using the familiar "power triangle" that is shown figure 2.

The relationship for power factor is:

$$PF = \frac{P_a}{P_t} = \cos\theta \tag{1}$$

In this circuit the power factor is determinate by software. For θ angle measurement the zero values of the current and tension are determinate. The filtering eliminate the harmonic influences of the measurement.

The time between the zero detection of tension and zero detection of current depends on power factor. The principle of determination is presented in figure 3.

The free timer of the microcontroller is started at the zero detection of the current and is stopped at the zero detection of the tension. The phase difference is determinate with the relation (2).

$$\theta = \frac{\Delta t}{T} 2\pi \tag{2}$$

For power factor determination (cos θ) a memorized in EEPROM internal table is used.

The capacitor bank is used for the power factor correction. The output signal of the PIC 16F84A microcontroller if a frequency modulated signal. The frequency modulated signal command a static commutation bloc for the compensation of the reactive power.

Adding power factor correction capacitors to a facility's electrical distribution system generally solves low power factor. Power factor correction capacitors supply the necessary reactive portion of power (kVAr) for inductive devices. By supplying its own source of reactive power, a facility frees the utility from having to supply it. This generally results in a reduction in total customer demand and energy charges.
Power factor correction requirements determine the total amount of capacitors required at low voltage buses. These capacitors can be configured as harmonic filters if necessary. The power factor characteristics of plant loads typically are determined from billing information, however, in the case of a new installation, typical load power factors will determine the required compensation.

For limiting inrush current pre-charge resistors are used. Pre-charge resistors can give a far better performance. However, some series inductance may still be desirable to handle current-dump situations from charged capacitors.

Protection at over voltage of the capacitors is realized with diacs.
Moreover, the value of 1.1Vn may also be approached only max 8 hours every 24 hours, before considerable capacitor degradation sets in.

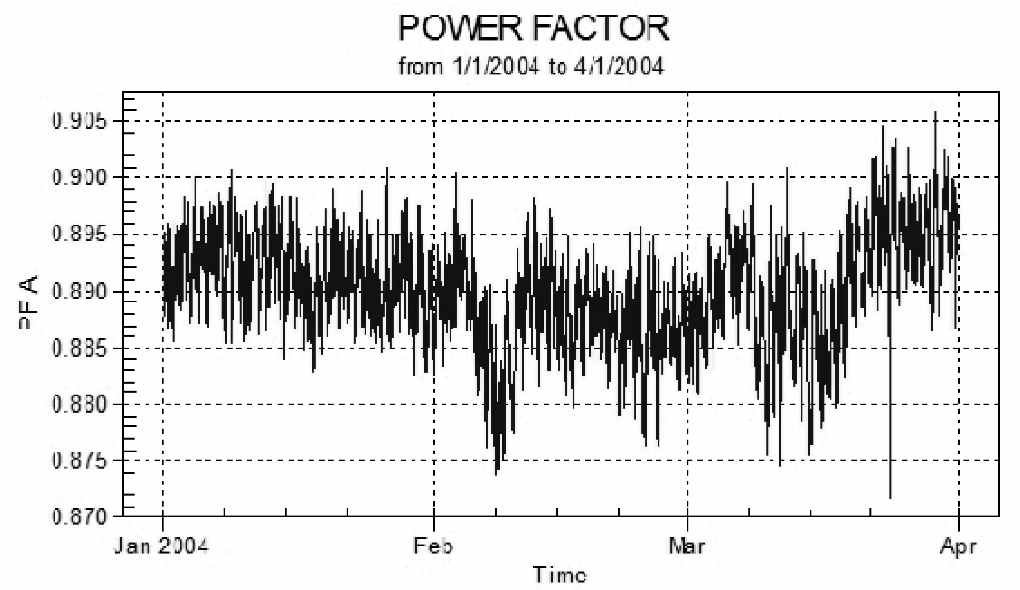

Figure 4. The power factor variation.

The power factor compensation circuit has a serial communication with the computer. The serial communication assures the acquired parameters transmission of the computer.

In same manner the user can modify the parameters memory of the command circuit for adaptation at the particular situations.

Finally the LCD display allow local exhibit of the parameters. The main parameter displayed is the instantaneous power factor. The power factor in a facility will vary over time. An example trend of a facility's power factor over three-months is shown in the figure 4. Power factor will also vary with different types of loads, and the overall mix of various types of loads. Inductive loads, such as motors, will tend to reduce the power factor. Linear loads, such as lighting, will tend to increase power factor.

5. CONCLUSIONS

Automatic power factor control improves energy efficiency. This is both a significant competitive edges in the global context as well as a national priority.

Well-designed and well-used microcontroller technology further adds to that efficiency by reducing the lifetime cost of the equipment to the end user.

This paper has examined simple and effective steps to reach this goal.

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