A MICROCONTROLLER-BASED STATIC VAR COMPENSATOR FOR UNBALANCED LOADS

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ABSTRACT

The authors report the development of the laboratory model of a microcontroller-based Static Var Compensator (SVC). A prototype of an automatically controlled voltage balancer using thyristors valves to switch the capacitors and inductors has been investigated. A digital control scheme incorporating a microcontroller is developed.
At each sampling time, the loading conditions are measured by a voltage transducer and sent to the SVC controller. Accordingly, the microcontroller, the heart of the system, adjusts the voltage to the desired value. This is achieved by controlling a thyristorised static var compensator through microcontroller software. In this paper, experimental results are given.

INTRODUCTION

The recent attention to exploring the fast switching compensator for mains voltage support and distortion correction has occured for the following major reasons [1]:

- A focus on power quality, there is a growing concern to try to reduce the power system pollution which has been caused by ever-increasing number of power electronics loads.
- Recent advances in power semiconductor technology which have significantly improved the speed-power characteristics of switches.
- The availibility of powerful single-chip microcontrollers**.**

From the distribution authorities point of view, an important factor, which has a significant impact on power quality, is the higher background harmonic levels and unbalanced load in the power systems caused by nonlinear loads [2].
In power system operation, balanced three-phase transmission and distribution systems are normally assumed to be balanced. However, unbalanced load currents resulting from unbalanced loads are usually encountered in distribution systems. A great number of a single load and three-phase Y-connected loads are connected to radial distribution feeders. Both industry and domestic equipment are sensitive to voltage changes above or below a given magnitude. To high a voltage may lead to insulation failure, damage to components or mal-operation of electrical equipments, to low voltage results in unsatisfactory performance [2][3].
the development of thyristor-valves capable of handling large currents, as well as the technique of using them to switch capacitor in and out and control the current trough a reactor, have provide the power system with a new tool to meet reactive power generation and absorption demands [3].
It can be used to achieve one or more of the following task [4][5]:

- Regulating the supply voltage within the specified limits about the desired steady state value under normal operating condition.
- Compensation of the voltage fluctuation caused by the reactive power demand of large and fluctuating industrial load.
- Compensation of the voltage variation under unbalanced load.
- Power factor correction and harmonic current compensation.

The paper discusses the development of a microcontroller based automatic voltage balancer by using low voltage switched capacitors and reactors for reactive power compensation [6][7]. The compensation value of each phase voltage is measured and sent to the microcontroller board which determines the on/off connection of the capacitor or the conductor by firing the corresponding thyristors in each phase. The paper proposes a real time microcontroller-based voltage profile correction scheme for unbalanced load on distribution systems.

SYSTEM DESIGN

Since the main cause of the voltage variation and unbalance on an LV distribution system is the variation of loads and their unbalance, in this section, the possible method of voltage control and reducing the phase to an acceptable level based on an SVC is introduced [7][8]. The main goal is that the voltage in each phase can be increased or deceased by injection or absorption of reactive power from the network by switching a capacitor or linear inductor respectively. In fact, at time of an excessively low voltage, so as to bring a low voltage to acceptable level, a certain amount of capacitance should be switched in. Meanwhile, in case of a high voltage, an amount of linear inductor should be switched in. So for each phase one inductor and capacitor (or both of them) have to be allocated.
In reality, the voltages of all three phases simultaneously becoming too low or to high do not occur. However, the most cases noticed within the Algerian distribution system are either one phase high, one low and the other within

stationary limits or one phase high and the others low. The latter is related to a single phase load which is the worst case. Hence, in our case, the development of an automatic static voltage balancer corresponding to the latter case has been considered.
In fact, most of the loads taken from the LV distribution are domestic loads; the requirement is to maintain the voltage of three phases within stationary limits. This leads to the reduction of zero sequence voltage and current as well. In this situation, it is not necessary to make any effort to reduce or eliminate the negative sequence voltage, and there is no need for independent control for each phase in order to attempt to equalize the three line voltages. Hence, due to the above mentioned points, the number of capacitors and inductors involved can be reduced to two inductors and one capacitor instead of three inductors and three capacitors. The complete system is designed around the MCS51 family of Intel microcontrollers. The 87C51.microcontroller and the associate circuits measure the voltage of each phase, generate the firing pulses for each thyristor and detect the capacitor coincidence with its reference voltage as shown by fig.1.

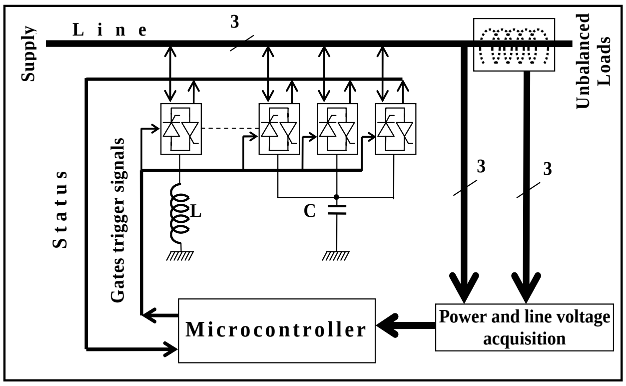

Fig.1 Bloc diagram of the simplified digital voltage balancer

Data acquisition for three phases system

According to the previous section, the overall arrangement data acquisition for three phase system is shown by the bloc diagram of fig. 2 where the main modules of the whole system are illustrated: step down and isolation module, an analog multiplexer module, low pass filter and zero crossing detector. An analog to digital converter is added in order to facilitate an instantaneous reading of the phases voltages by the microcontroller. The zero crossing detector permits the detection of negative and positive half-waves and hence reading the peak of the corresponding half wave. The main advantage of this structure is its ability to detect the presence of a DC component.
Thus by this arrangement the most efficient use of hardware is made under practical condition. The performance of the controller depends on the quality of information presented to it. The transducers which provide this information must be able of responding accurately and quickly to the changes of the measured variables. The fundamental requirement is that the voltages to be measured must be stepped down by factors that would not render the measured values inaccurate and hence unreliable. Harmonics and spikes or transients which may exist on the output voltage transformer and lead to the mal-operation of the control system and damage the analogue to digital converter circuit, must be eliminated by the filter.
The output from the filter is therefore a pure sinusoidal which is then rectified, the rectification being performed by a precision rectifier which overcome the 0.7 volt drop associated with diodes when used in more conventional rectifier circuits.

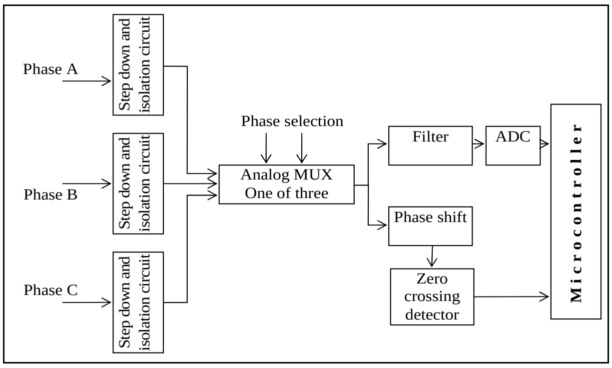

Fig.2 Bloc diagram of data acquisition system

Control system elements

The microcontroller, which is used as part of the control system in voltage balancer, must be able to respond to the analog electrical quantities. The analog electrical quantities (i.e. Voltage) are to be converted into digital values suitable for the microcontroller by using an ADC converter. The bloc diagram of the completed control system is shown in fig.3.
For the purpose of a transient free switching of the capacitor, the switching must take place when its charged voltage has the same polarity and reaches the maximum value of the supply voltage. This can be achieved by either digital or analogue approach.
In the digital approach, the charged capacitor voltage is converted to a digital value by means of either separate A/D converter or using the existing A/D converter. The latter which is more economical can be used. The digital value corresponding to the capacitor voltage is compared with the digital equivalent of supply voltage, so as, to recognise the correct time of switching the capacitor. A subroutine within the software can provide these requirements.

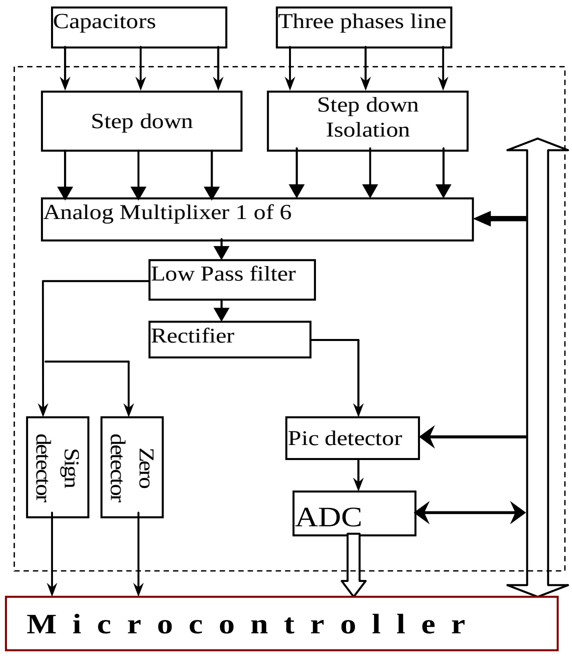

Fig.3 Control system architecture

Software development

The Intel 87C51 microcontroller is used in order to perform the control function. The software developed coordinates the role of the various hardware components, measures the electrical quantities, processes and generates the firing pulses to the thyristors to connect in or out either the capacitors or the inductors. A flowchart of the program is shown in fig.4 , it should be noted the flowchart illustrate the polarizing and repolarizing of the capacitor. For convenience, subroutines have been used whenever possible, since they had to be used more than once in most cases.

EXPERIMENTAL RESULTS

The proposed voltage balancer scheme was implemented and tested at the laboratory of microprocessor and technology at the University of Batna. The load is provided by three variable resistive loads (range from 0.5 to 30A) with a number of steps. Also by connecting a linear inductor in series with a variable load. The supply voltage used is 220 volts, 50Hz and the case considered is one phase low whereas the two others are maintained high which represents the common case that occurs in the distribution systems; this is the result of a heavy load one phase or a single phase load. The measurement are taken by switching on respectively the value of C=60µf on phase A, L_1=142mH on phase B and L_2=242 mH on phase C.

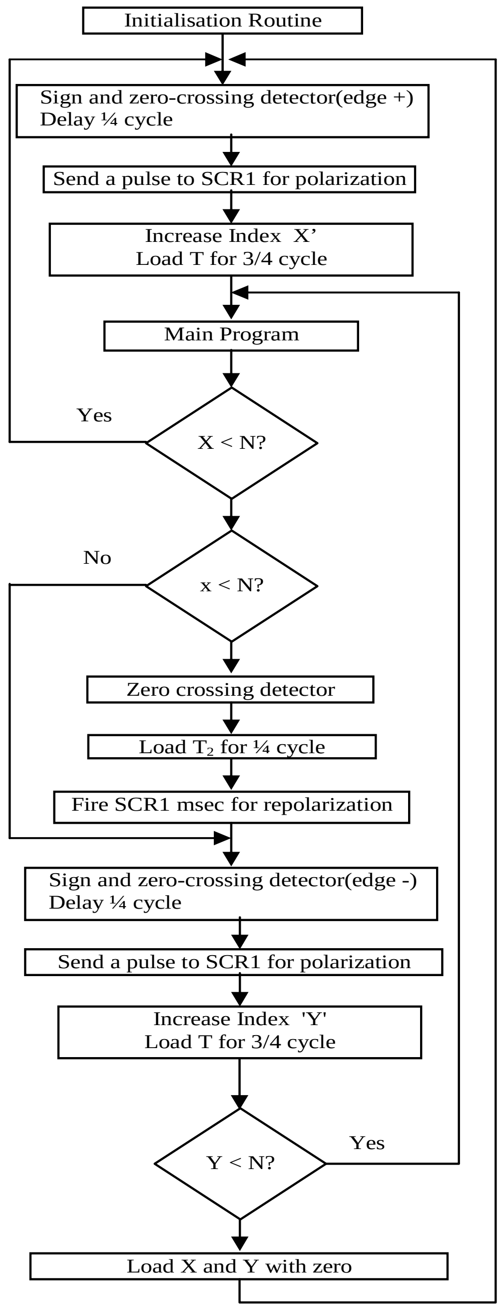

Fig. 4 Flowchart diagram of the developed software

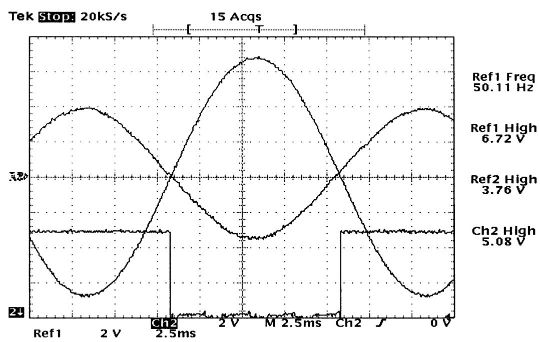

Fig. 5 Signal output from active filter, multiplexer and pick detector

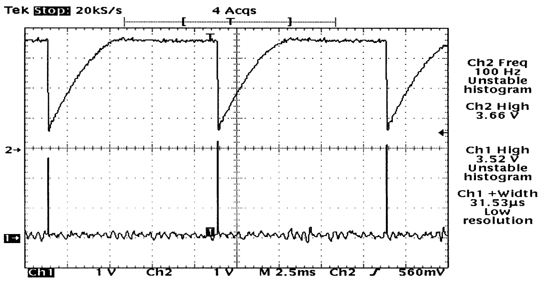

Fig.6 Impulse signal of Synchronizing circuit

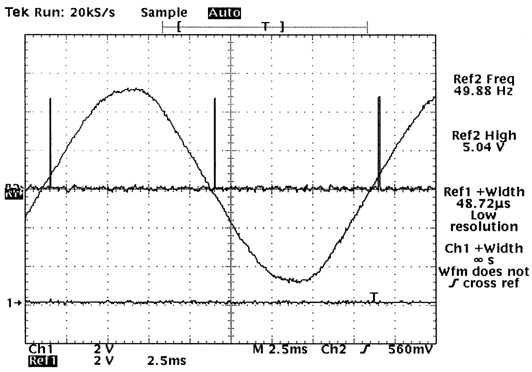

Fig.7 Voltage wave form of phase1

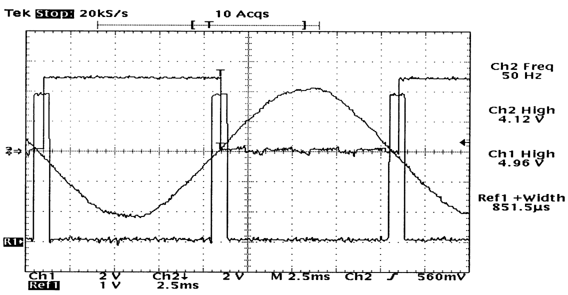

Fig. 8 Zero detector output

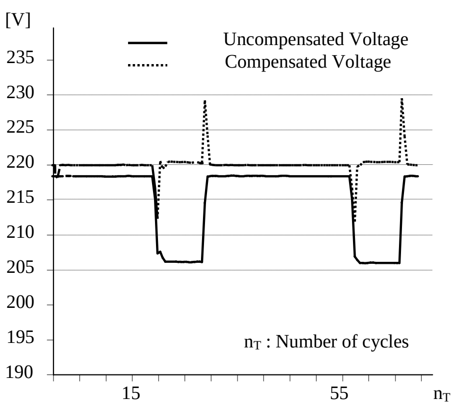

Fig. 9 Response of the SVC

CONCLUSION

A static reactive power compensator SVC, which consists of thyristor-controlled reactors and controlled capacitor,is designed and impleemnted to improve the voltage profile ofan unbalanced system.At each sampling insatnt the loading conditions are measured by voltage trabsducer and sent to the SVC controler which is constructed on a microcontroller board.The proposed model is experemently verified and is found to give very fast and precise compensation characteristics. Detail are given for the experimental system as well as the control algorith implementation.Balancd voltage on the test system demonstrates the effectuveness of the developed control strategy for the compensator

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