論文
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Realtime Digital Monitoring and Controller Development for Power Systems
(전력시스템의 실시간 디지털 중앙감시 및 제어장치 개발)

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ABSTRACT

In this paper, We propose digital protective relay which monitors the status of distribution line and controls power apparatus with real time operation. Digital protective relay improves the performance of basic functions which are measurement, display and communication. The first one we consider is that the protective device has the standard method for protecting the distribution systems which are circuit brakers, switch and emergency generators. These are protected by analog type protective relay and devices. The security requirements should be activated within a few seconds, and with real time operation. The second one is an efficient method for adapting the one chip micro-processor(PIC16F84) which is enable to digital control system. The proposed methods are implemented with experimental results and have an high fidelity characteristics in local experiment tests.

요 약

기존의 전력 시스템 보호 장치는 아날로그 방식으로 고성능, 고기능화를 지향하는 전력 설비의 장치로는 동작의 신뢰도를 높일 수 없으며, 또한 배전용 전력 시스템의 중앙감시 및 제어 장치로 표준화시키지 못한 문제점이 있다. 수배전 보호장치와 비상용 발전 설비의 제어장치를 디지털 방식으로 전환시켜 집약적이고, 고성능의 전력 시스템 감시 및 제어 기능을 갖도록 한다. 전력 시스템의 동작 및 상태(전압, 전류, 전력, 위상 및 주파수)를 실시간 디지털 방식으로 계측하고 통신방식을 사용하여 감시하고 제어하는 통합 중앙 감시 및 제어장치 개발을 목적으로 한다. 이러한 전력 감시 설비를 마이컴 방식[1,2]을 채택하여 디지털 제어가 가능하며 집약적이고 고성능의 감시 및 제어기능[3]을 갖도록 하였다.

1. Introduction

Although the digital protective relay filed of power system growing for decades, there are several problems in cases of the high fidelity and maintenance of digital power protective equipment. Especially, the distribution protective devices which are circuit braker, switch and protective relay, and the emergency generator are controlled by the analog type protective relay systems. Therefore recently, the controllers of distribution protective device and emergency generator are converted into the digital type devices which have the supervising and control functions of compressive and high performance.

The status of power system is monitored and controlled by the communication function, The advanced generator control function is activated by

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one-chip microprocessor which is the 8 bit PIC family microprocessor. The display units used the custom LCD which improved the making process and simplified the displaying modes for current, voltage and other variables. The membrane switch is consisted of a name plate and switch module which adjust the operating conditions, the mode selections and the power system variables. In this study, we proposed the improvement of graphic processing function for power system parameters which are the phase currents, active/reactive power, power factor, and the phase balance. The algorithm of power system control is processed within the real time loop with PIC microprocessor.

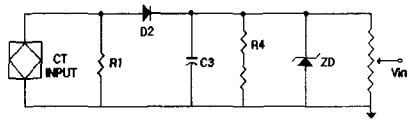
2. Circuit Design and Layout

2.1 Circuit Design

1) Input Terminal Circuit

The input static and dynamic protection circuits are designed to isolate the inputs to the power lines when a large voltage is applied, with protecting the CMOS chip from static spike voltage. Almost to the PIC16 family microprocessors[4,5], this protection circuit is two large P-N diodes on each input terminal. These diodes will short any voltage higher than Vdd to the Vdd supply and any voltage less than Vss to the Vss supply. They can take several milliamps of current without any damage to the chip. High voltage can be applied directly to the chip inputs as long as they have current limit function. The least expensive method of current limiting is using a high value resistor. This method is shown schematically in [Fig. 1]

The resistor R1 improves the filter characteristics of condenser C3 which has the value of 10uF. The diode D2 removes the ripple for additionally improving the half rectification. The resistor R4 reduces the operating time and ripple signal. The zener diode ZD adjusts the input voltage bandwidth. Therefore the variable resistor R6 adjusts the input voltage and operating current to the input terminal of PIC A/D converter.



[Fig. 1] Protection circuit of I/O Pin

2) Current Transformer Circuit

The current transformer converts high input current into the low voltage which is applied to the input terminal of PIC I/O pin. The turn ratio of current transformer is first unit 1.2mm/1T and second unit 0.18mm/400T. These circuits are designed to increase the input resistance, and reduce output resistance. The thickness of Z core is 0.35mm in the transformer which is allowed for flowing input current. The 1A of CT input current generates the 5V of input terminal voltage.

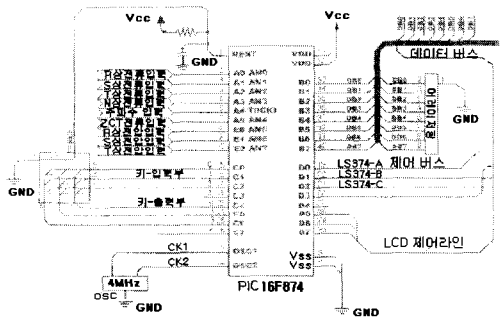
3) Current Data Processing

The operating current of digital circuit is divided into the 10 steps in the basis of operating time intervals. When 1st input 1A current is 100% setup in long time base, the experimental current value is compared to the actual current value for verifying the difference value of input voltage. Therefore, the digital input value is 255 which applied to the full input voltage 5V. Additionally for setting the short time current and ground current on the basis of time setup, we adjust the CT input circuit and filter circuit, and update the current setup value on the PIC program.

2.2 Circuit Layout

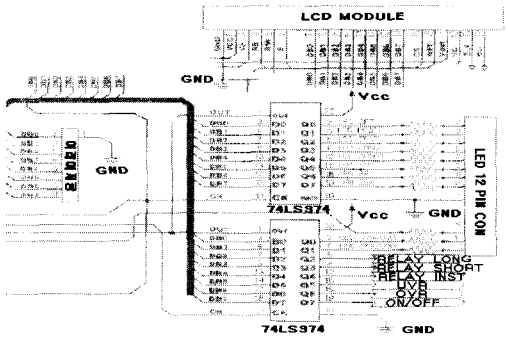
1) Power Supply Unit

The switching mode power supply inputs the AC 220V/60Hz by two channels, and outputs the DC 24V/5V/GND terminals. The input unit is shown schematically in [Fig.2] Actually, the operating voltage is AC, DC 30V - 240V 50,60Hz free voltage mode.



[Fig. 2] Input Circuit Layout

The power line is connected to the CT terminals and transformers. The input currents flow to the resistors and transistors. See [Fig. 3] It is also recommended that the CPU circuits have the I/O interfacing to the input and output terminals, and the data filtering and processing units.



[Fig. 3] Interfacing Circuit

3. Experiments

3.1 High Performance Digital OCR

1) Hardware Performance

The long/short time characteristics of over current relay convert into the reverse time characteristics which accurately operate the digital relay. The operating time characteristics are enable to select the various time characteristics with the strong reverse, instantaneous reverse, and reverse time characteristics. The input voltage resolution is improved to 10 bit resolution. The setup range is 20 steps with before being compared to 8 steps.

2) Multi Function Display

The current[A], voltage[V], consume active power value[W], power factor[PF] and line frequency[Hz], reactive power value[Var] are shown in the multi function display units. The units are the same with the MKS unit system. Especially, the phase unbalance status of power line is displayed in the bar graphic window.

3) Arithmetic and Input Unit

The CPU type is the PIC16F874[4] which is the DIP 40 pin type. The clock frequency is the 4MHz. The expansion output is enable to connect IC 74LS374. The input voltage is supplied by each phase mode. When the input voltage is AC 100V, the converted DC voltage has the rippled 3V voltage. And also, the input currents are supplied by each phase mode. When the input current is 1A, the converted current is 0.05A by the intermediate CT. The converted current 0.05A is applied to the resistor and bridge diode, and finally converted into about 3V voltage value.[8]

4) Various Trip Functions

The digital relay has the trip functions which are long-time, short-time, instantaneous, and ground trip operations. Especially, the ranges of ground trip are 10% - 40% level of the nominal value. And also it has the 0.2A - 0.4A leakage current protection function. When the line current being unbalanced, the unbalanced trip operation is happened. The above trip functions protect the power apparatus and electrical machine from the electrical shock damages. [9]

3.2 Software Configuration

Software is divided into between hardware control part and digital relay operation program part.

1) Hardware Control

The hardware of digital relay has the LCD, key input part, A/D converter, EEP-ROM, relay operation part, timer setting, LED driving part, multi-function protection part, and hardware initialization part. Almost software of hardware control part is the PIC assembly language program.

2) Digital relay Program

Digital relay is operated by the assembly program which accurately calculates the various arithmetic and logic operations. The relay programs are the phase current / voltage calculation and analysis, the line frequency, the phase difference analysis, the power factor, the active and reactive consume power, the number of time characteristics, the grounding current and the test trip mode selection functions.

3.3 Experiment Results

1) Current Characteristics

[Fig. 4] shows the long time current and short time current characteristics at the operating time base through the switch direction. At the long time experiment, the sampling time is 0.5 second. But at the short time experiment, it is 0.01 second.

LONG TIME SET = REF (5mSEC) X SAMPLING X DATA LT
SAMPLING TIME = 0.5 SEC

SWITCH	DATA_LT	RANGE
0	10	5
1	20	10
2	30	15
3	40	20
4	50	25
5	60	30
6	70	35
7	80	40
8	90	45
9	100	50

LONG TIME CURRENT SET = DATA LA

SWITCH	DATA_LA	RANGE
0	3	55%
1	5	60%
2	8	65%
3	10	70%
4	13	75%
5	15	80%
6	18	85%
7	20	90%
8	23	95%
9	26	100%

SHORT TIME SET = REF (5mSEC) X SAMPLING X DATA ST
SAMPLING TIME = 0.01 SEC

SWITCH	DATA_ST	RANGE
0	10	0.1
1	20	0.2
2	30	0.3
3	40	0.4
4	50	0.5
5	60	0.6
6	70	0.7
7	80	0.8
8	90	0.9
9	100	1.0

SHORT TIME CURRENT = DATA SA

SWITCH	DATA_SA	RANGE
0	51	200%
1	64	250%
2	77	300%
3	89	350%
4	102	400%
5	115	450%
6	128	500%
7	140	550%
8	153	600%
9	166	650%

[Fig. 4] Long/Short time current

[Fig. 5] shows the ground fault current characteristics. The ground fault of power line is not easily detected to the digital relay. Therefore, it is necessary for digital relay sensitivity to accurately monitor the fault current at the short time intervals. The sampling time is 0.01 second.

GROUND TIME SET = REF (5mSEC) X SAMPLING X DATA GT
SAMPLING TIME = 0.01 SEC

SWITCH	DATA_GT	RANGE
0	10	0.1SEC
1	20	0.2
2	30	0.3
3	40	0.4
4	50	0.5
5	60	0.6
6	70	0.7
7	80	0.8
8	90	0.9
9	100	1.0

GROUND CURRENT SET = DATA GA

SWITCH	DATA_GA	RANGE
0	140	20%
1	153	24%
2	166	28%
3	179	32%
4	191	36%
5	204	40%
6	217	44%
7	230	48%
8	242	52%
9	255	56%

[Fig. 5] Ground fault current

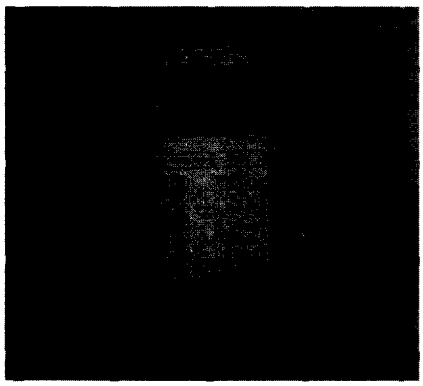
[Fig. 6] shows the instantaneous time current characteristics. The instantaneous current is very large value. Therefore, it is necessary for digital relay sensitivity to broadly monitor the operating currents.

INSTANT CURRENT SET = DATA IA VALUE		
SWITCH	DATA_IA	RANGE
0	140	550%
1	153	600%
2	166	650%
3	179	700%
4	191	750%
5	204	800%
6	217	850%
7	230	900%
8	242	950%
9	255	1000%

[Fig. 6] Instantaneous Current

The accomplished device is shown in the [Fig. 7] At this figure, we use the membrane switch for setting the operation parameters which are time, display, and other things.

Especially, the display unit represents the graphic data processing. For example, the current/ voltage values are displayed by bar graphic mode, and the status parameters are displayed by the capital letters for easily reading, if possible.[6]



[Fig. 7] Digital relay Layout

4. Conclusions

In this work, we present the digital protective relay model which improves the performance of relay, circuit braker, and switch. The communication function of relay control part is enable to monitor the status of power line parameters, to control the operation program , and to display the current / voltage, frequency, power value, and other parameters. The above functions are easily applied to the intelligent building system, factory apparatus, and other power equipments. Through this work, digital protective relay is progressively updated with O-Sung electricity Machinery CO., LTD.

Acknowledment

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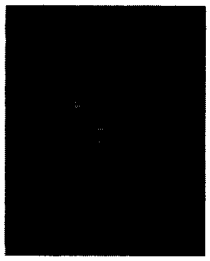
홍 선 학



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