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Automatic Generation Control Using Digital Techniques.

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AUTOMATIC GENERATION CONTROL USING DIGITAL TECHNIQUES

BY

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ABSTRACT:

Techniques for simulation and application of automatic digital generation control are presented. Objectives of generation control are reviewed. A digital control scheme is described and implemented. The presented directive software is capable of guiding the whole system so that control objectives are achived in a satisfactory manner.

1. INTRODUCTION:

Over the past decade digital computers have been installed by many electricity supply authorities and utilities to aid the control engineers and operators in both the operational planning phase and real-time control of power systems. By far, the majority of computer installations to-date serve in supervisory level; carrying out such duties as data logging, monitoring variables and checking for alarm conditions, contingency evaluations and economic dispatch calculations[1].

Recent advances in digital technology have resulted in tremendous reductions in digital component costs and improvements in reliability. These advances led to the use of digital components as integral parts in industrial systems and direct computer control has been the usual results of this integration.

Automatic generation control has evolved ...
the time when the junction was performed ...
the days of simple analog system ...
of sophisticated direct d...

Generation control i...
objectives[2,3]:

1) Matching area generatio...
2) Distributing these chan...
minimize operating costs ...
constraints such as migh...
derations.

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The use of digital computers and high speed data communication systems allows a new degree of freedom permitting, through software, the implementation of wide range of control techniques.

The key to the derivation of improved control techniques lies in the ability to test them on simulation models of the process and controls.

This paper presents a digital control scheme applied to a simulation model of a two-generating unit power-station. Test and operating software are included.

2. SIMULATION MODEL OF A GENERATING UNIT:

A generating unit is fully simulated by a separately-excited D-C motor drives synchronous generator. The output torque of the D-C motor is either armature-or field-controlled. The fastresponse is a cridet for the former control scheme.

3. PROPOSED DIGITAL GENERATION-CONTROL SCHEME:

Fig. 1 shows the proposed digital control scheme in which digital-to-analog converter (D/A), Analog-to-digital conveter (A/D), multiplexers (selector) and data transmission circuits form the necessary interface-requirements linking the computer to the power system under control.

The actual most economic load allocation on the various generating units are stored in the computer memory as a table. Control action to each individual unit is primarily a function of the unit's control error defined as the difference between desired and actual generation. This permits tuning of control action to the individual unit's dynamic response characteristics and provides unit control without overshoot since control action is in proportion to the error of the quantity being controlled.

Reallocation of generation may be guided through a com-
-and signal proportional to the frequency. This command
-gnal comes from a tachometer mounting on the rotating
-ft of the generating unit. The ability to relocate gene-
-n on command, offers a complete automatic feedback
-l control system which can be of particular value in
-c implementation of system security measures.

-upervisory routine which directs the interaction
-puter and controlled system is visualized by the
Fig. 2.

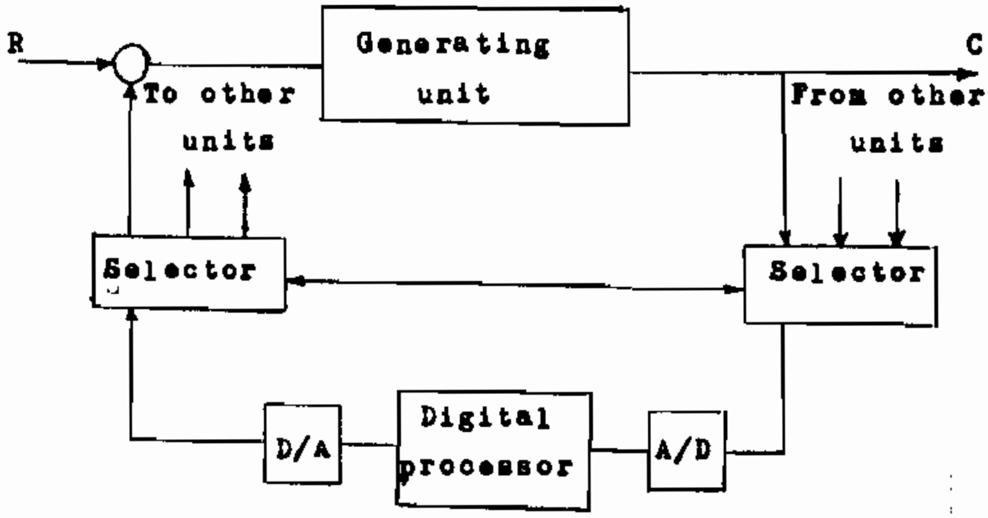

Fig.(1): Digital Generation Control

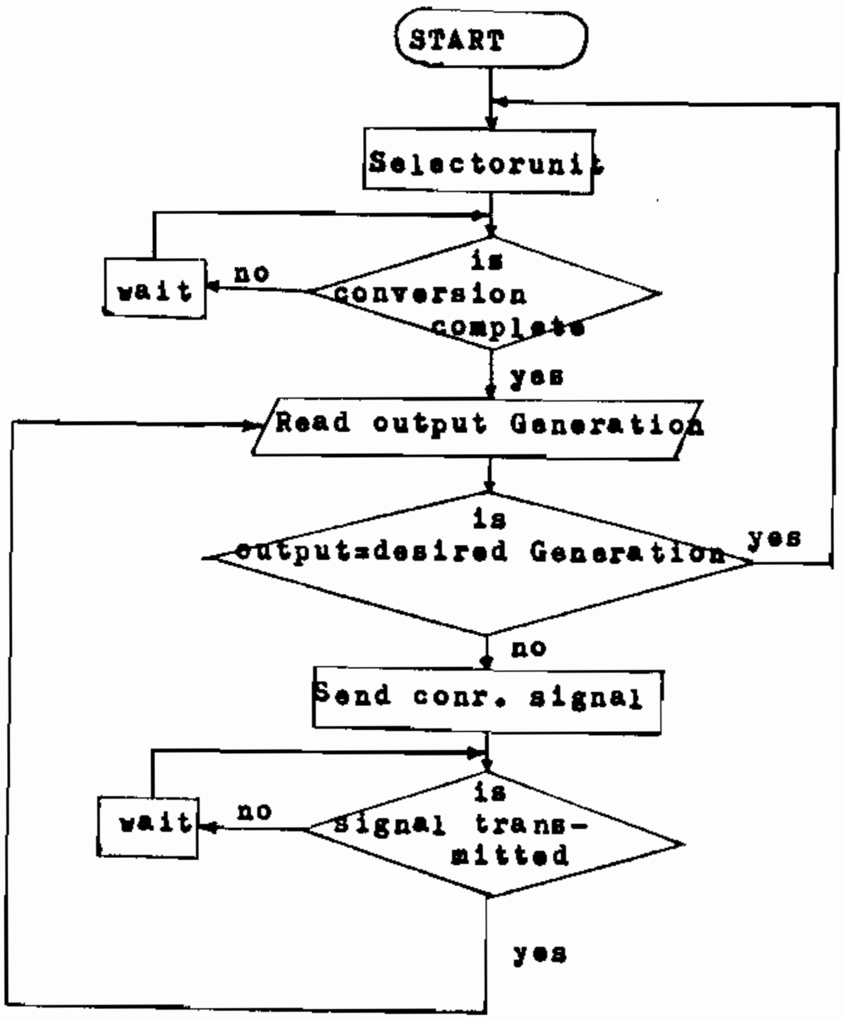

Fig.(2): Flowchart of control logic.

Control actuation time depends on conversion speed (or resolution) of the A/D used. Usually, such devices have two extra bits (or pulses). Start conversion and conversion complete are the two extra pulses which are used as interrupt signals the time between which represents control actuation time.

4. SOFTWARE REQUIREMENTS:

Programming computers for direct applications and control is usually carried out using Assembler Language associated with the computer.

PAL-11 Assembler is the program which translates symbolic language into absolute binary code capable of being executed by the PDP-11 family of computers. The symbolic language or source program in PAL-11A language is composed of a sequence of statements which can be edited and punched on a paper tape by the PDP-11 Text Editor Program ED-11.

Accordingly, four extensive programs were developed using the computer's assembly language and the text Editor. Listing of the four programs is given in the appendix. Program one tests and adjusts the performance of the digital-to-analog converter. Program two examines the closed loop embodying all devices of the digital control scheme. Program three is a final program which directs the control process on a two-interconnected power generating units.

If a forcasting routine is available to predict the power demand in advance, it may be operated in conjuction with program four which operates the system automatically according to a time-power schedule.

According to program four the computer loads the whole system automatically with a new load every two minutes which is proportional to an octal number of 2100 in the program.

5. CONCLUSION:

Conclusively, automatic digital generation control is implemented and is satisfactory working, using a simulation model. Loading and control processes are programmed and the necessary software is given. We are looking forward to the day in which these simulation techniques are in practical working order.

6. REFERENCES:

1. K.J. Runtz *et al*., "Digital Control Scheme For a Generating Unit" IEEE-Trans., Vol. PAS, 1973, pp. 478-483.

2. F. P. DeMello *et al*., "Automatic Generation Control", IEEE-Trans., Vol. PAS-, 1973, pp. 710-722.

3. H. J. Fiedler *et al*., "Automation Developments in the Control of Interconnected Electric Utility Systems", Proceeding of the IEEE, Vol. 57, No. 5, 1969, pp. 744 - 750.

7. APPENDIX:

Software programs in assembly language.

7.1. Program One:

```
;TEST PROGRAM FOR THE DIGITAL/ANALOG CONVERTER

                 AVEC = 310
               STAVEC = 312
               ADCOUT = 167754
                DACIN = 167752
                ADCSR = 167750
                 KEYS = 177570
                   R0 = %0
                   R1 = %1
                   R2 = %2
                   R3 = %3
                   R4 = %4
                   R5 = %5
               . = 3000
START:         MOV #340 , STAVEC        ;PRIORITY OF SEVEN DURING
                                        ;INTERRUPT
               MOV #4000 , AVEC         ;ADRESS OF SERVICE ROU-
                                        ;TINE TO INTERRUPT VECTOR
               MOV #100 , ADCSR         ;ENABLE INTERRUPT A
               HALT                     ;LOAD KEYS
BEGIN:         MOV KEYS , R5
               MOV R5 , KEYS
TEST:          MOV R5 , DACIN
               CLR R0
DELAY:         INC R0
               CMP R0 , #6250.
               BNE DELAY
               CMP KEYS , R5
               BEQ TEST
               JMP BEGIN
               . = 4000
               RTI
               .END START
```

*

7.2. Program Two:

```
/L
                  ;   TEST PROGRAM FOR THE CLOSED LOOP
                  ; CONTAINING THE A/D AND D/A CONVERTERS

                  AVEC = 310
                  STAVEC = 312
                  ADCOUT = 167754
                  DACIN = 167752
                  ADCSR = 167750
                  KEYS = 177570
                  R0 = %0
                  R1 = %1
                  R2 = %2
                  . = 1000
START:            MOV #340 , STAVEC
                  MOV #4000 , AVEC
                  MOV #100 , ADCSR
                  MOV #101777 , R1
LOAD:             MOV R1 , DACIN
                  CLR R2
LOOP:             INC R2
                  CMP R2 , #6250.
                  BNE LOOP
READ:             TSTB ADCSR
                  BPL READ
                  MOV ADCOUT , R0
                  MOV R0 , KEYS
                  DEC R1
                  JMP LOAD
                  . = 4000
                  RTI
                  .END START

*
```

7.3. Program Three:

```
; THE FINAL PROGRAM WHICH CONTROLS THE ECONOMIC POWER ALLOCATION
;          ON TWO INTERCONNECTED POWER UNITS

                 AVEC = 310
               STAVEC = 312
               ADCOUT = 167754
                DACIN = 167752
                ADCSR = 167750
                 KEYS = 177570
                   RØ = %Ø
                   R1 = %1
                   R2 = %2
                   R3 = %3
                   R4 = %4
                   R5 = %5
               . = 3000
START:         MOV #340 , STAVEC          ;PRIORITY OF SEVEN DURING
                                          ;INTERRUPT
               MOV #4000 , AVEC           ;ADRESS OF SERVICE ROU-
                                          ;TINE TO INTERRUPT VECTOR
               MOV #100 , ADCSR           ;ENABLE INTERRUPT A
               HALT                       ;LOAD KEYS
BEGIN:         MOV KEYS , R5
               CMP R5 , #7777
               BLE READY
               MOV #7777 , R5
READY:         MOV #1000 , R4
LOOP:          CMP R5 , @R4
               BLE STEADY
               ADD #20 , R4
               JMP LOOP
STEADY:        MOV R4 , R3
               MOV @R3 , KEYS
LOAD2:         MOV R3 , R4
               MOV #40000 , R2
               ADD #4 , R4
               ADD @R4 , R2
DONE2:         MOV R2 , DACIN
               CLR RØ
DELAY2:        INC RØ
               CMP RØ , #6250.
               BNE DELAY2
               MOV ADCOUT , R5
               CMP R5 , #1153
               BLE CONT2
               MOV #41133 , R2
               JMP ADJ2
CONT2:         MOV R3 , R4
               ADD #54 , R4
               CMP R5 , @R4
```

*

```
                BLE LOAD1
                SUB #30 , R4
                MOV #40000 , R2
                ADD @R4 , R2
ADJ2:           MOV R2 , DACIN
                CLR R0
WAIT2:          INC R0
                CMP R2 , #6250.
                BNE WAIT2
LOAD1:          MOV R3 , R4
                ADD #12 , R4
                MOV #100000 , R1
                ADD @R4 , R1
DONE1:          MOV R1 , DACIN
                CLR R0
DELAY1:         INC R0
                CMP R0 , #6250.
                BNE DELAY1
                MOV ADCOUT , R5
                CMP R5 , #2103
                BLE CONT1
                MOV #101000 , R1
                JMP ADJ1
CONT1:          MOV R3 , R4
                ADD #46 , R4
                CMP R5 , @R4
                BLE TEST
                SUB #14 , R4
                MOV #100000 , R1
                ADD @R4 , R1
ADJ1:           MOV R1 , DACIN
                CLR R0
WAIT1:          INC R0
                CMP R0 , #6250.
                BNE WAIT1
TEST:           CMP KEYS , @R3
                BEQ SKIP
                JMP BEGIN
SKIP:           JMP LOAD2
                .=4000
                RTI
                .END START
(
*
```

7.4. Program Four:

```
; THE FINAL PROGRAM WHICH CONTROLS THE ECONOMIC POWER ALLOCATION
;         ON TWO INTERCONNECTED POWER UNITS

                  AVEC = 310
                STAVEC = 312
                ADCOUT = 167754
                 DACIN = 167752
                 ADCSR = 167750
                  KEYS = 177570
                    R0 = %0
                    R1 = %1
                    R2 = %2
                    R3 = %3
                    R4 = %4
                    R5 = %5
                 . = 3000
START:           MOV #340 , STAVEC         ;PRIORITY OF SEVEN DURING
                                           ;INTERRUPT
                 MOV #4000 , AVEC          ;ADRESS OF SERVICE ROU-
                                           ;TINE TO INTERRUPT VECTOR
                 MOV #100 , ADCSR          ;ENABLE INTERRUPT A
                 HALT                      ;LOAD KEYS
INIAT:           MOV KEYS , R5
                 MOV #1000 , R3
                 CMP R5 , @R3
                 BNE BEGIN
                 MOV #41777 , DACIN
                 CLR R0
STAY2:           INC R0
                 CMP R0 , #6250.
                 BNE STAY2
                 MOV #101777 , DACIN
                 CLR R0
STAY1:           INC R0
                 CMP R0 , #6250.
                 BNE STAY1
                 JMP INIAT
BEGIN:           ADD #20 , R3
                 CMP R3 , #2140
                 BLE PAUSE
                 MOV #1000 , R3
                 JMP BEGIN
PAUSE:           CLR @#1016
                 MOV @R3 , KEYS
LOAD2:           MOV R3 , R4
                 MOV #40000 , R2
                 ADD #4 , R4
                 ADD @R4 , R2
DONE2:           MOV R2 , DACIN
                 CLR R0
```

*

```
DELAY2:      INC RØ
             CMP RØ , #625Ø.
             BNE DELAY2
             MOV ADCOUT , R5
             CMP R5 , #1153
             BLE CONT2
             MOV #41133 , R2
             JMP ADJ2
CONT2:       MOV R3 , R4
             ADD #54 , R4
             CMP R5 , @R4
             BLE LOAD1
             SUB #3Ø , R4
             MOV #4ØØØØ , R2
             ADD @R4 , R2
ADJ2:        MOV R2 , DACIN
             CLR RØ
WAIT2:       INC RØ
             CMP RØ , #625Ø.
             BNE WAIT2
LOAD1:       MOV R3 , R4
             ADD #12 , R4
             MOV #1ØØØØØ , R1
             ADD @R4 , R1
DONE1:       MOV R1 , DACIN
             CLR RØ
DELAY1:      INC RØ
             CMP RØ , #625Ø.
             BNE DELAY1
             MOV ADCOUT , R5
             CMP R5 , #21Ø3
             BLE CONT1
             MOV #1Ø1ØØØ , R1
             JMP ADJ1
CONT1:       MOV R3 , R4
             ADD #46 , R4
             CMP R5 , @R4
             BLE TEST
             SUB #14 , R4
             MOV #1ØØØØØ , R1
             ADD @R4 , R1
ADJ1:        MOV R1 , DACIN
             CLR RØ
WAIT1:       INC RØ
             CMP RØ , #625Ø.
             BNE WAIT1
TEST:        INC @#1Ø16
             CMP @#1Ø16 , #21ØØ
             BNE SKIP
             JMP BEGIN
SKIP:        JMP LOAD2
             . = 4ØØØ
             RTI
             .END START
```