# Disturbance Recorder

Z. Eškinja, I. Mišković, M. Stipanov
Brodarski Institute
Ave. V. Holjevca 20, Zagreb, Croatia
Tel: +385 (0)1 650 43 51 Fax: +385 (0)1 650 44 00 E-mail: zdravko.eskinja@hrbi.hr

**Abstract – Process data recorded just before a system breakdown have a significant meaning in modern industries. These informations help to resolve system failure cause and prevent error reoccurrence. A safety backup implementation into PLC system is limited due to low memory and similar performance issues. The paper presents a method for compressing and recording process data using a PLC and an operator panel. The main advantage of this method is placing important information on a secure location: external nonvolatile memory card and remote station with Ethernet connection. The system is designed and tested for emergency stop sequence in hydro plant turbine governing system.**

## I. INTRODUCTION

In industrial production process is under constant attention to preserve quality and avoid system breakdown. Every transient event after unexpected emergency stop needs to be recorded and analyzed. The regulation is usually placed on programmable logical controller (PLC) where all process signals are monitored and controlled (Fig. 1 – 1).

The work presented here describes a method for safety backup in hydro plant turbine governance. The goal is to save at least four minutes of process variable data and place it on remote location that is easy to access.

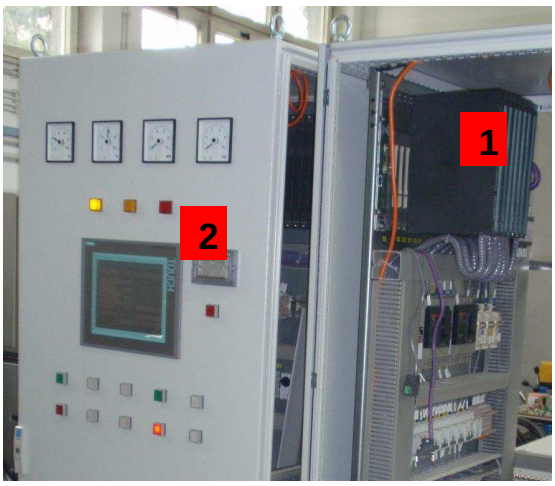


**Fig. 1** Motor drivers and controllers

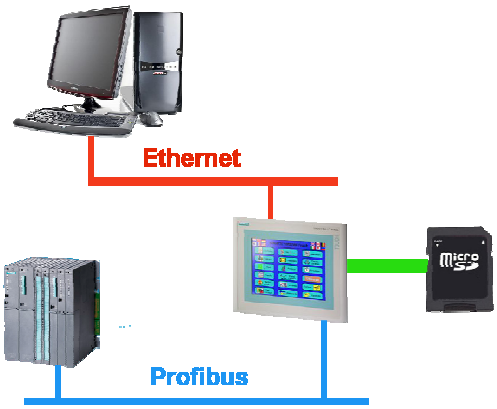


**Fig. 2** System network

Few solutions are standard for performing similar tasks in automated recorder systems. One of them is additional CPU with massive database designed for real system backup data, and second is PAC (Programmable Automation Controller) like NI CRIO which can replace the existing system CPUs .

Both methods are easy to develop, but expensive. Their use require changing the technology what is not an option. SCADA (Supervisory Control And Data Acquisition) system usually use insufficiently low sampling time to collect real time process data directly.

Safety backup implementation into the PLC system is limited due to low memory and similar performance issues. Thereby, the disturbance recorder tasks cannot be runned by the PLC. For accomplishing such tasks, it is neccessary to use three components (Fig. 2):

- PLC,
- Operator panel (OP) (Fig. 1 – 2). and
- Personal computer (PC).

The application has no effects on production quality, speed or reliability loss of process control. Connection failure or panel disfunction will not stop production.
SCADA can be used with or instead operation panel in disturbance recorder system.

## II. DISTURBANCE RECORDER

The base element of disturbance recorder is the PLC. The PLC has an FlashEPROM card but writing files is not possible [1] because it is used as the main memory for the process program code. The solution lies in the OP used for user interface (Fig. 1 – 2). The OP has its own Micro SD card. The PLC and the OP are connected over profibus network, and the OP is connected with remote PC through the ethernet network.

PROFIBUS DP (Process Field Bus Decentralized Peripherals) is a standard for field bus communication and is used to operate sensors and actuators through a centralized controller in production (factory) automation applications.

The memory amount exceeds the limits in PLC's data blocks (DB). Wanted data occupies 216kb of memory, and the DB's max size is 64kB. The process data is being stored in circular list made of 4 DB's (Fig. 4). Data is refreshed by each cycle. Signal sampling time is 20 miliseconds. The transient event or manual switch triggers the data transfer with an arbitrary delay if it is needed to record what happens after.

Software in OP gets the data package by package. Size of the package is a 3.186kB because of the array limit size in the OP. When package is received, the data is written to MMC, and the OP is ready for another package.(Fig. 3)

It is obvious the transfer is the bottleneck and speed of disturbance recorder depends on number of packages. Also, the disturbance recorder code in the PLC requires 225MB and that is more than 90% of whole data memory for regulation code. The reason why the memory overloads is in five DBs used as data storage and transfer buffer. The key of improvement is in the data compression. The best fit method for PLC is Run-Length Encoding (RLE). Main advantages are simplicity and good results for short transient events [2].

## III. DATA COMPRESSION

The basic principle consists in coding a first element by giving the number of repetitions of a value and then the value to be repeated [3] (Fig. 5).

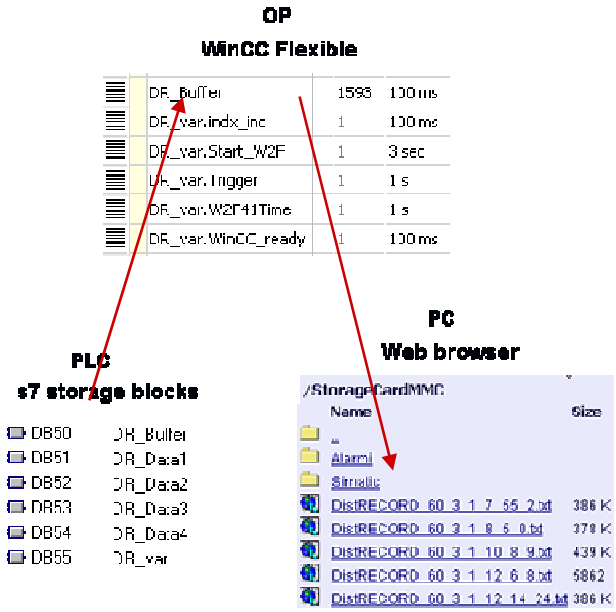


**Fig. 3** Data flow - recorded data in different envirements

Thus, according to this principle, signal "00005555555555555555555" when compressed yields "4(0)19(5)". The compression gain is:

$$\eta = \frac{\quad}{Ns} = \frac{\quad}{23} \qquad (1)$$

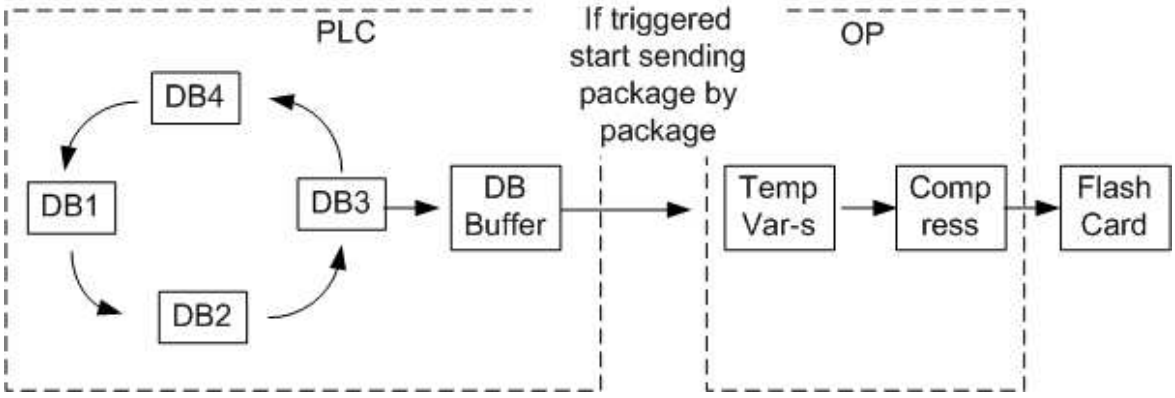


Fig. 4 Algorithm scheme

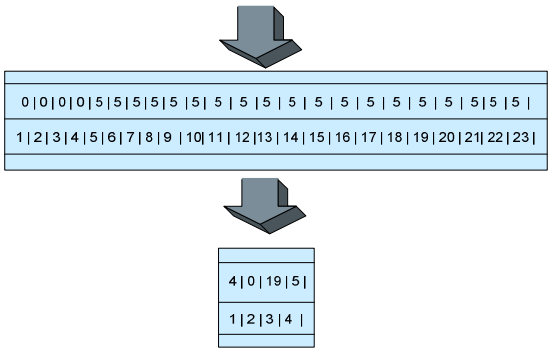


**Fig. 5** Visual explanation of RLE

$\eta$ - efficiency coefficient,
Ns – signal data chain,
Ncs - compressed signal data chain,

that is, approximately 82.6% On the other hand, for the signal where there is little value repetition the result of the compression has negative compression gain. In the worst case , for example 01234567 , the gain is -50%!

Actually, RLE compression is governed by particular rules which allow compression to be carried out when necessary and the chain to be left as it is when compression causes a waste. These rules are the following:

- If three or more elements are repeated consecutively, the RLE compression method is used
- If not, a control character is inserted, followed by the number of elements of the non-compressed chain and then the latter
- If the number of elements of the chain is odd, the control character is added on the end
- Finally, specific control characters were defined in order to code:
  - end of signal
  - end of all data

RLE schemes are simple and fast, but their compression efficiency depends on the type of signal data being encoded. A digital signal will encode very well, due to the large amount of contiguous data that is all of the same value.

An analog signal in value transition which is very dynamical, such as turbine speed in safety stop sequence, will not encode very well. That is because the complexity of the signal is expressed as a large number of different values [4], and because of this complexity there will be relatively few runs of the same value.

The basic flow of RLE algorithm is illustrated in Fig. 6.

## IV. EXPERIMENT RESULTS

The algorithm is implemented in hydro plant turbine government which is designed using Siemens Automation equipment. All process variables were simulated by a model of *Francis* turbine. Graphs shown in figures (Fig. 7 and Fig. 8) present recorded signals of transient events triggered manually.

Recorded signals in graphs present variables used in turbine governing system. First four are analog and the last is digital. Variables interact and behave due to known physical rules. Any system failure, process deviations and even system component deterioration can be noted observing the signal value response on certain events [5].

- **Gate opening** – [0-100%] - the wicket gate opening - control signal
- **Turbine speed** – [0-100%] - speed is presented in relation to nominal turbine speed.
- **Active power** – [MW] - the current produced electric power
- **Gate opening reference** – [0-100%] – reference given by some process program or manually
- **Isolated operation** [0%-OFF;
25%- ON] – digital signal which denotes activation of grid independent operating mode

Change that comes from interconnected to isolated operation of the electric power system causes dynamical response of the turbine speed and other system variables. Variable overshot and oscillations should be under predefined limits, otherwise it is an indicator on some component degradation and possible future system failure.

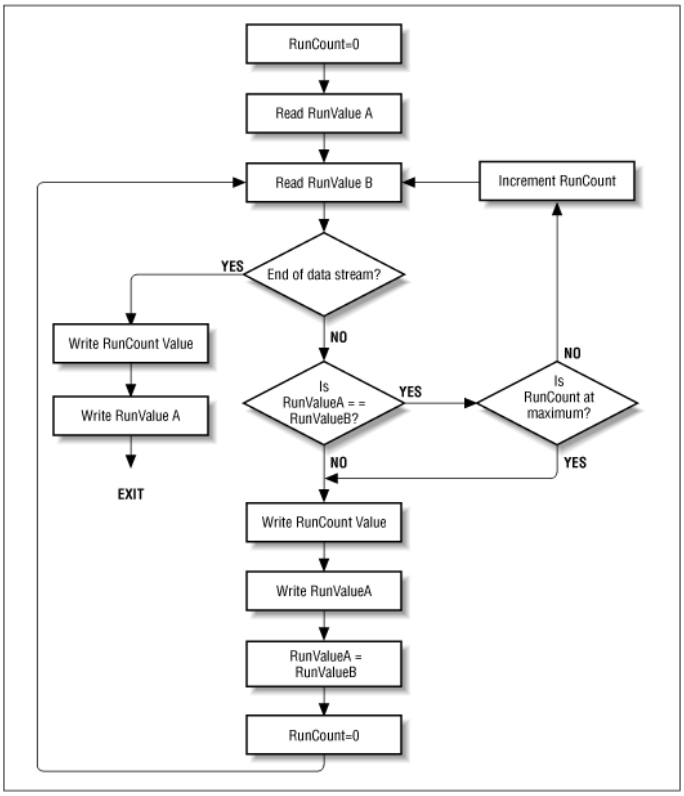


**Fig. 6** Flowchart

The signal alternation is reserved only for specific variables during the transient event. The other part of record is in the most cases very constant so there is enough space for RLE compression and the efficiencies are more then 70 percent [6]. The data transition works faster if the event life time is shorter.

## V. CONCLUSION

The RLE compression makes sense to use in process signals logging because there exists many consecutive repeated elements - large uniform areas.

Solving advanced tasks in automation by using low capability system requires multi device co-operability and alternative mathematical method. The application of the integrated post-failure approach, here described as the specific example of the hydro plant turbine government system, shows how several components can cooperate and contribute to completion of the transient recorder system.

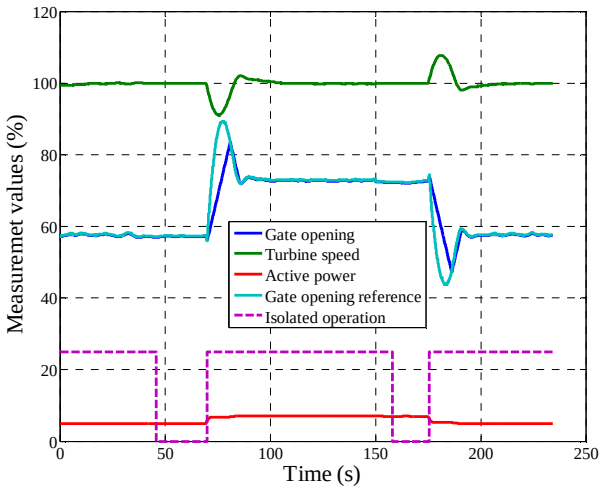


**Fig. 7** Signals response while changing the working mode

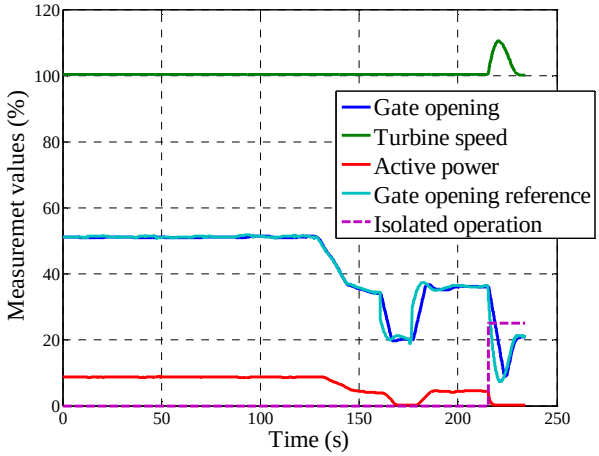


**Fig. 8** Signals response while changing the wicket gate

## REFERENCES


[1] System Software for S7-300/400 System and Standard Functions, Siemens, Reference Manual December 2002, pp 283 – 350.

[2] K Sayood, “Introduction to Data Compression”, Academic Press, 2000,USA pp. 13-35

[3] D Salomon, “Data Compression”, the complete reference, Computer Science Departement, Californica State University; Northridge,2007, pp. 17-42.

[4] M. Burrows , D. J. Wheeler , M. Burrows , D. J. Wheeler, “A block-sorting lossless data compression algorithm” (1994), pp 763-783.

[5] F.D. Anger, R. V. Rodríguez, M. Ali.,” Industrial and engineering applications of artificial intelligence and expert system” Overcas publisher organisation, Amsterdam 1996., pp 67-81.

[6] L. M. Thompson, “Industrial data communications”, ISA, 2002,USA, pp. 13-26