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DISTRIBUTED ARCHITECTURES FOR AN INTEGRATED MICROPROCESSOR BASED SUBSTATION CONTROL AND PROTECTION SYSTEM

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ABSTRACT. This paper is concerned with a problem of selection of distributed architectures for the microprocessor-based systems. These systems are a substitution for the classical data acquisition, control and protection apparatus located in Electric Power Transformer Substations. Study of the data flow within the Substation is given first. Description of the basic elements of the architecture is also presented. The possible architecture layouts are presented in the next section. Some conclusions are given at the end.

1. INTRODUCTION

The research area of Integrated Substation Control and Protection Systems is in an early development stage [1]. So far, there is only one Integrated System commercially available in the world produced by the Mitsubishi Electric Company of Japan [2].

Application of microprocessors enables a great variety in designing architectures for the Substation Control and Protection applications [3]. Distributed system architectures for the Integrated Systems represent complex problem. Careful analysis of various system parameters such as reliability, availability, maintainability, flexibility, utilization, speed of operation and the cost must be taken into account in order to define hardware, software and communication architecture requirements [4].

This paper gives a system analysis [5] which enables better understanding of the architecture requirements. Various configurations for the distributed architectures are indicated. Finally, the most atractive architectures are defined.

2. DATA FLOW WITHIN A SUBSTATION

Results of the system analysis of the data flow [5] indicate that there are three basic data acquisition and processing levels within a substation:

- substation switchyard
- control and protection gear
- substation coordination system

Substation switchyard level is where the data is collected. The data sources are the measurement and protection transformers as well as the switchgear status contacts.

Control and protection gear level is where the data is processed using digital control and protection algorithms [6]. Outputs of this level go into two directions. One direction is towards the switchgear located in the switchyard. The other direction is towards the substation coordination system where the overall substation data is collected.

Substation coordination system level is where the local SCADA functions are performed. Therefore, at this level data is processed for the purposes of the data presentation as well as for the purposes of the supervisory control for the overall substation.

Further analysis is needed to indicate the required data paths between the mentioned levels. These data paths are determined by functional requirements and by needed data sharing among various functions.

Particularly are interesting the protection functions. It can be noted that the data gathered at any one breaker is always required by two and only two protection functions. This is because all the breakers connected to a bus provide data for the protection of that bus as well as for protection of either a line or a transformer.

Similar analysis for some of the control functions indicate that there are different data paths required for input and output of data to these functions. An example is the switching sequences function which can obtain the input data from one set of breakers and according to that information can produce the tripping signals which use different data paths to reach another set of breakers.

3. BASIC ARCHITECTURE ELEMENTS

It is possible to define the basic building blocks which are needed to construct a distributed, microprocessor-based architecture [4]. The next paragraph gives a brief description of these building blocks.

P - processor. This is a microprocessor which executes digital algorithms for data acquisition, control and protection.
A - data acquisition unit. Enables analog and digital data acquisition as well as digital data output.
L - line interface. This interface appears in a point-to-point data link. It performs parallel to serial data conversion and vice versa.
H - data highway interface. It appears in a multipoint serial link and performs data conversion and data transfer arbitration functions.
Data Highway. It is a high speed serial data link which is used in a multipoint link configuration.
Serial link. It is a high speed point-to-point link.
System bus. It is a parallel multiprocessor bus.

4. DATA ACQUISITION AND PROCESSING CONFIGURATIONS

This analysis is related to the possible configurations of the following subsystems of a Distributed Microprocessor-Based Control and Protection System:

- data acquisition subsystem
- control and protection subsystem

Data acquisition subsystem is located in the substation switchyard. It can be configurated in the three different ways shown in Figure 1.

The first possibility (common link) is implemented using either parallel or serial data link which connects all the data sources in the switchyard. Therefore, required data for the monitoring, control and protection functions is available on this data link. Each of the functions located at the higher levels in the system can obtain the required data by an appropriate data link connected to the common data link.

The second possibility (separate link) assumes that each of the functions obtains the required data through a dedicated link which is directly connected to the desired data source. Therefore, each data source has as many connections as there are users of the data from this particular data source.

The third possibility (divided link) uses a single link connected to a data source.However, this link is split into two data links which are used by two different functions. Further use of the data from this source is provided by performing a retransmission of the data from one of the two ends of the divided link to a third location within the system where some additional functions reside.

Control and protection subsystem consists of a number of microprocessors dedicated to various control and protection functions including the overall substation coordination functions. This subsystem can be implemented in the three possible ways shown in Figure 2.

The first solution (common link) assumes that all the processors at the control and protection level as well as at the substation coordination level are connected to a common serial or parallel data link. In this case all the data exchanges among the processors are done over this common data link.

The second solution (common link with a crosslink) assumes that all the processors are connected in the same way as in the first solution. However, processors at the control and protection level are also connected to each other through a crosslink.

Finally, the third solution (clustered link) assumes that several processors at the control and protection level are connected to each other with a parallel link. Therefore, the processors are grouped in several clusters of processors. These clusters are then connected to each other with crosslinks. However, all the clusters are also connected to a high speed data link which enables exchange of data among clusters for the purposes of the cluster coordination.

5. SELECTION OF THE MOST SUITABLE ARCHITECTURES

Taking into account performed analysis [1] as well as the method for this analysis [5], one can define three the most atractive solutions. These solutions are outlined in Figure 3. The basic elements of the architectures given in Figure 3 are discussed in the Paragraph 3 of this paper.

Architecture given in Figure 3-a uses completely independent data paths from the data sources to the control and protection processors. The data path is implemented using a fiber optic data link which connects the data acquisition unit and the parallel bus of the related processor. This configuration is most like existing relay practice. Its main advantage is that it retains the most separation of functions by allocating these functions to a separate hardware. This means, for example, that specific hardware exists for each different line protection relay, separate and distinct from all other line protection relays. This configuration rates highly in modularity and adaptability to different substation situations, but it does not eliminate hardware duplication. Its wiring savings are not as great as in other configurations.

Architecture given in Figure 3-b is quite similar to the architecture given in Figure 3-a. The basic difference is in the fact that two processors are grouped together in a cluster in Figure 3-b. This enables use of the common data link to bring the required data from the switchyard. therefore, the improvements in the hardware utilization and wiring cost reduction are achieved. However, some of the modularity and adaptability achieved in the Figure 3-a architecture are traded for this cost reduction. This solution still assumes separation of the protection functions by allocating them to separate processors. Nevertherless. the fact that two processors are in the same cluster implies certain hardware and software dependability not present in the classical protection systems.

Architecture given in Figure 3-c also assumes that several processors are grouped in a cluster. Required data is brought to the clusters using unique data paths. Further distribution of the data from one cluster to some of the others is done through a crosslink. This solution is the most attractive as far as the data link hardware and the wiring are concerned. Levels of modularity and adaptability are decreased becouse of the presence of crosslinks. Also, a time delay is introduced by transmitting the data to one cluster and then retransmitting it to some other cluster.

6. CONCLUSIONS

The results of the previous analysis indicate that:

- selection process for the distributed microprocessor based architectures to be applied in the Electric Power Substations is quite a complex problem,
- solution of this problem requires definition of appropriate methods and criteria for selection,
- the latest hardware, software and communication solutions should be properly understood in the contex of the Integrated System applications.

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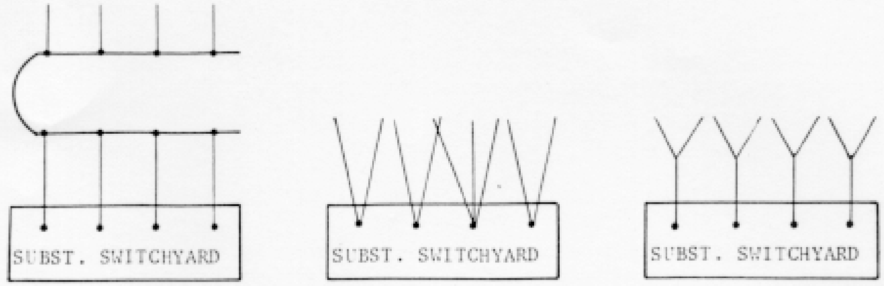
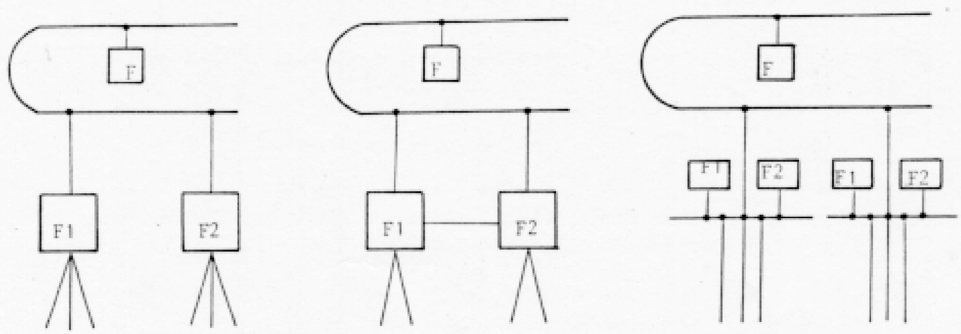


Figure 1. THREE DIFFERENT WAYS FOR CONFIGURATING DATA ACQUISITION SUBSYSTEM



F1,F2 - Level of the Control and Protection Functions

F - Level of the Substation Coordination Functions

Figure 2. THREE DIFFERENT WAYS FOR CONFIGURATING CONTROL AND PROTECTION SUBSYSTEM

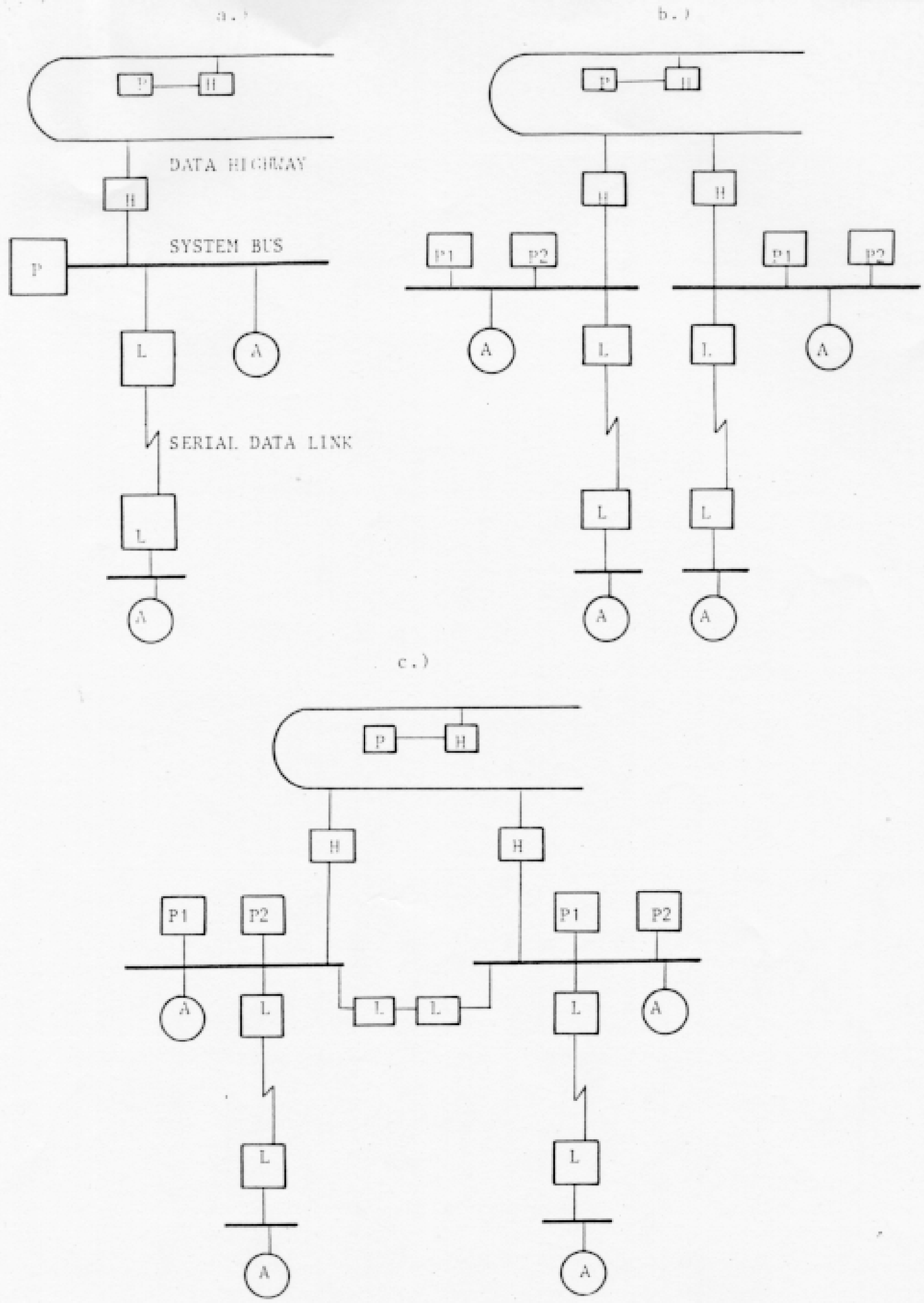


Figure 3. THE MOST ATTRACTIVE DISTRIBUTED SYSTEM ARCHITECTURES