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Buses Architecture of Substation Automation System Based on Significance Level of Substation

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Abstract: One of the important issues in a substation automation system is performance of the communication buses consist of station bus and process bus. The station bus provides communication between station level devices and bay level devices and the process bus provides communication between bay level devices and primary equipment. In substation automation system, the appropriate operation of protection, control and monitoring systems depends on communication network accuracy. The communication network architecture is based on the required data, reliability and commissioning requirements during the installation of the SAS (Substation Automation System). It is clear that the reliability and security of the communication networks are different respect to importance of the substation. Therefore, the significance of the substation can be used to determine the communication network and inside the substation bus configuration. In this study, a new approach is proposed to determine the significance level of substation based on 7 factors and then the architecture of communication buses has been configured.

Key words: Substation automation system, communication network, station bus, process bus, IEC 61850 standard

INTRODUCTION

Nowadays, by applying IEC 61850 in substation automation system, IEC 61850-8-1 standard protocol used for station bus communication, Also, process bus as a serial communication network with IEC 61850-9 protocol replaced conventional wiring (Andersson *et al*., 2008; Brunner *et al*., 2002; Apostolov, 2006; Vadiati *et al*., 2008a; Hodder *et al*., 2009; McGinn *et al*., 2009). Figure 1 shows communication architecture in SAS (Substation

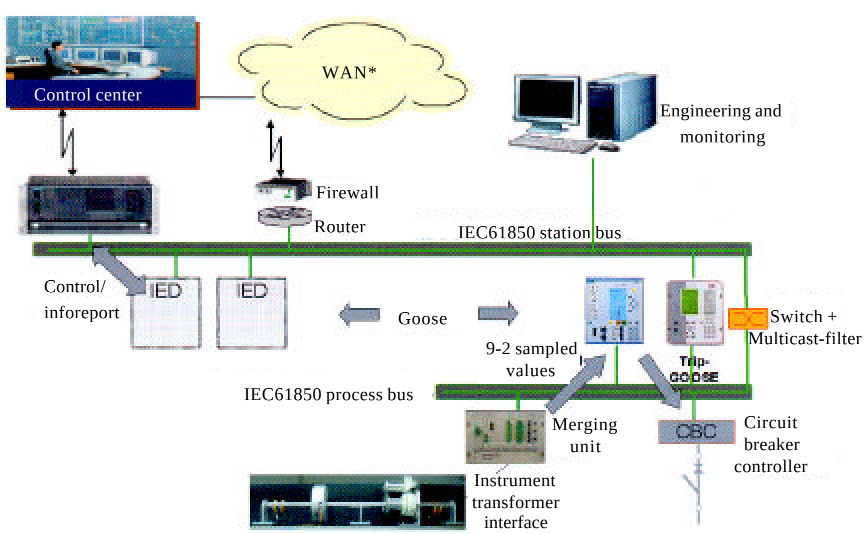

Fig. 1: Typical architecture of modern substation

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Automation System) by applying IEC 61850 Standard. Regarding to modern SAS, all data are transferred from process that consist of primary equipment to SAS via serial communication network by applying digital switchgear according to IEC 62271-3 and remote I/Os, sensors and actuators in process level (Engler *et al*., 2004; Brunner, 2005; Hossenlopp *et al*., 2008; McGinn *et al*., 2008). Appropriate operation of SAS depends on the communication network performance and the performance requirements depend on the significance level of substation in power system (IEC 61850, 2003; Vadiati *et al*., 2008b). This study, introduced a new approach to determine the significance level of a substation. This approach is based on 7 factors, as will be discussed in this study, that they are similar in both transmission and sub-transmission substations, then, the configuration of the station bus and process bus will be explained based on the proposed method.

THE SIGNIFICANCE INDICES OF SUBSTATION

Several factors must be considered to determine the significance of substation. In this study, seven factors are used in determination of significance level of substation as discussed below:

- The substation capacity equals to total capacities of transformers or bus bars
- Quantity of power transformers
- Type of the substation bus bar arrangement including multi circuit breakers, main and transfer bus, double, ring, simple bus bar and etc.
- Quantity of 63 kV (or higher) incoming and outgoing feeders
- Location of substation in power network (i.e., radial or ring)
- The significance of the substation depends on substation location in the power network and load significance of its feeders. Therefore, substations can be classified as follows:

- **Very important substations:** This group includes the substations that should not be disconnected from the network even for a short time. Disconnection of these substations result in instability or black out of power network or regional blackout
- **Important substations:** This group includes the substations that could be disconnected for some minutes. The permanent disconnection of these substations adversely affect on the network. The consumption loads of these substations are high
- **Normal substations:** This group includes the substations that could be disconnected for several hours. The consumption loads of these substations are low

The significance of the operation functions is different based on bus bar types and others; therefore, this topic is important for determination significance level of the substations.

Sub-transmission substations significance level

Evaluation criteria: To determine the significance level of sub-transmission substation, the evaluation criteria and the scores are proposed for each index according to the Table 1. These factors and scores are obtained based on survey on 31 sub-transmission substations in Iran with different configurations and specifications. These criteria have been tested on them. The results have been compared with the proposed method of IEC 61850 -1/Annex A. The result of comparison shows that this method is more accurate than IEC one.

Determination and decision: After the determination of the evaluation criteria, the sum of scores determines the significance index for the sub-transmission substations:

- If the sum of scores is lower than 9 or equals to 9 then the substation will have low significance level and it will enumerate in S1 group
- If the sum of scores is higher than 9 then the substation will have high significance level and it will enumerate in S2 group, these results are shown in Table 2

Transmission substations significance level

Evaluation criteria: To determine the significance level of transmission substation, the evaluation criteria and the

Table 1: The evaluation criteria in order to determine significance index of sub-transmission substations

Row	Index	The evaluation criteria	Score
1	Substation capacity (MVA)	Sum of S/S capacity≥ 50	2
		Sum of S/S capacity<50	1
2	No. of transformer (by attention to development in future)	Sum of transformer No.>2	2
		Sum of transformer No. ≤2	1
		Without transformer	0
3	Type of bus bar in substation	Multi circuit breakers	2
		Double, ring	1
		Simple	0
4	No. of I/O feeders greater than 63 kV or equal to 63 kV (by attention to development in future)	No.>10	2
		2<No.≤10	1
		No.≤2	0
5	Location of substation in power network	Ring	2
		radial	1
6	The significance of the substation in power network	Very important	0-4
		Important	
		Normal	
7	The significance of operation functions	-	0-4

Table 2: Determination of significance level of sub-transmission substations

Substation type	Sum of scores	Significance level
Sub-transmission	Sum≤9	Low (S1)
	Sum > 9	High (S2)

Table 3: The evaluation criteria in order to determine significance index of transmission substations

Row	Index	The evaluation criteria	Score
1	Substation capacity (MVA)	Sum of S/S capacity≥500	2
		Sum of S/S capacity<500	1
2	No. of transformer (by attention to development in future)	Sum of transformer No.>2	2
		Sum of transformer No. ≤2	1
		Without transformer	1.5
3	Type of bus bar in substation	Multi circuit breakers	2
		Double, ring	1
		Simple	0
4	No. of I/O feeders greater than 63kV or equal to 63kV (by attention to development in future)	No.>10	2
		4<No.≤10	1
		No.≤4	0
5	Location of substation in power network	Ring	2
		Radial	1
6	The significance of the substation in power network	Very important	0-4
		Important	
		Normal	
7	The significance of operation functions	-	0-4

Table 4: Determination of significance level of transmission substations

Substation type	Sum of scores	Significance level
Transmission	Sum<9	Low (T1)
	Sum≥9	High (T2)

scores are proposed for each index according to the Table 3. These factors and scores are obtained based on survey on 21 transmission substations in Iran with different configurations and specifications. These criteria have been tested on them. The results have been compared with the proposed method of IEC 61850 -1/Annex A. The result of comparison shows that this method is more accurate than IEC one.

Determination and decision: After the determination of the evaluation criteria, the sum of scores determines the significance index for the transmission substations:

- If the sum of scores is lower than 9 then the substation will have low significance level and it will enumerate in T1 group
- If the sum of scores is higher than 9 or equals to 9 then the substation will have high significance level and it will enumerate in T2 group, these results are shown in Table 4

THE DETERMINATION OF THE COMMUNICATION NETWORK ARCHITECTURE

Appropriate communication network Architecture should be obtained based on significance level of substations. According to this approach, there are two choices for station bus architecture as follows:

Alternative 1: The station bus is accomplished with a station-wide communication bus, with the ability to handle all types of data to link computer server and gateway to the bay units. This choice is generally applicable for T1 and S1 types.

Alternative 2: This choice consists of a segmented communication bus connected by routers or bridges to process the large amount of data from the connected equipment. The segmentation should be designed to eliminate the need to pass fast data via routers. In some cases it may be applied with duplicate (redundant) communication bus architectures. This choice is generally applicable for T2 and S2 types.

Also, In order to obtain appropriate architecture for process bus, transmission and sub-transmission substations can be classified based on regions. There are many choices respect to executive problems, but in this research the regions are classified based on the bay zones. In this method the substation is divided to the regions considering primary equipment collection that performs common tasks in the bay. After regions classification based on bay zones and the determination of the significance indices, process bus architecture must be determined. For this purpose, there are three choices as follows:

Alternative 1: The process bus with separate configurations and routers for each region. In this case, each bay has an independent process bus; in addition, there is a common connection bus that is used by control and protection equipments for data transfer to other regions. The Data of each region is transferred to common connection bus by the each region-installed routers. This selection is generally applicable for T2 and S2 types.

Alternative 2: The process bus with multi regional configurations is similar to the previous configuration, but it supports several bays. The data is transferred from different regions by the routers. This choice is applicable for different types (S1, S2, T1 and T2).

Alternative 3: The process bus is accomplished with singular connection configuration without router. In this method, a single bus exchanges the data. This configuration does not need the routers but the data traffic increase on buses. This choice is applicable for S1 type.

Buses architecture in sub-transmission substations: The earlier results about station bus and process bus architecture of sub-transmission substation are shown in Table 5.

Table 5: Determination of buses architecture in sub-transmission substation

Significance level	Station bus architecture	Process bus architecture
Low (S1)	Alternative 1	Alternative 2,3
High (S2)	Alternative 2	Alternative 1,2

Above result about determination of process bus architecture has been applied on typical S1 substation is shown in Fig. 2.

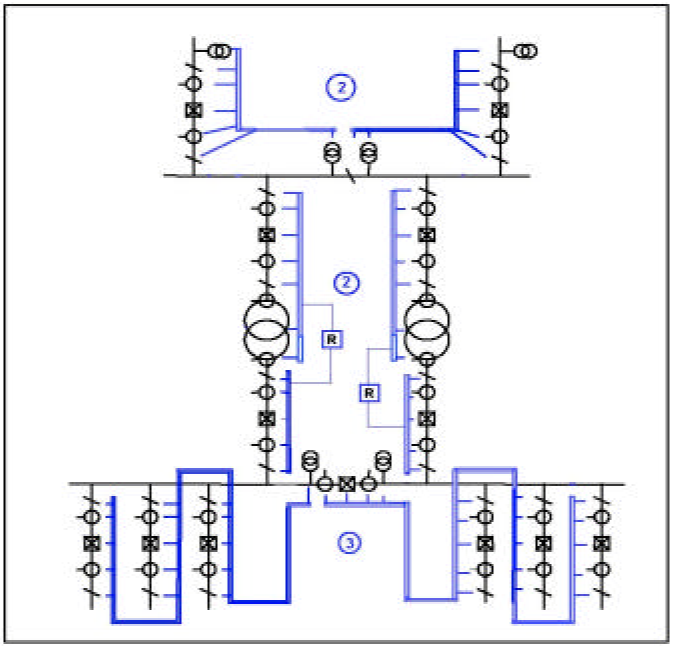

Fig. 2: The process bus configuration based on alternative 2 and 3 in a sub-transmission substation (S1)

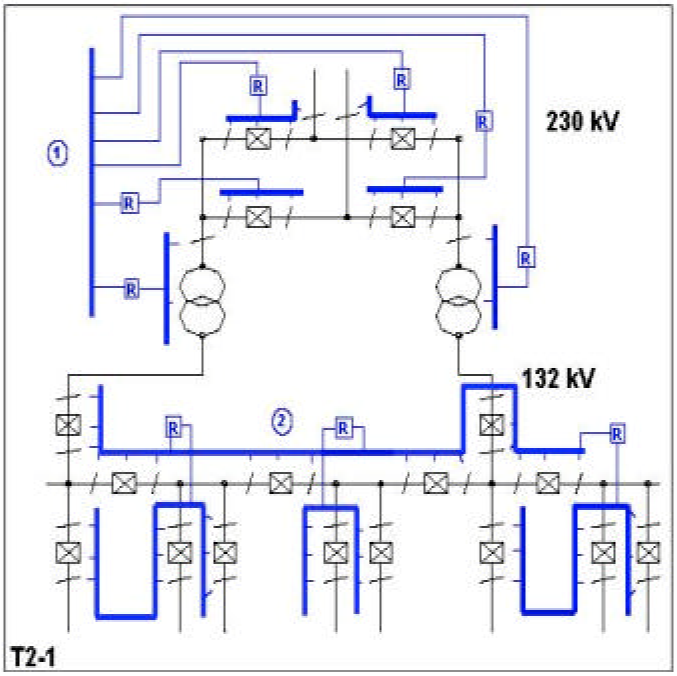

Fig. 3: The process bus configuration based on alternative 1 and 2 in a transmission substation

Table 6: Determination of buses architecture in transmission substation

Significance level	Station bus architecture	Process bus architecture
Low (T1)	Alternative 1	Alternative 2
High (T2)	Alternative 2	Alternative 1,2,3

Buses architecture in transmission substations: The earlier results about station bus and process bus architecture of transmission substation are shown in Table 6.

Above result about determination of process bus architecture has been applied on typical T2 substation according to Fig. 3.

CONCLUSIONS

In the substations, the appropriate operations and reliability of SAS depend on communication network performance, which is based on architecture of station bus and process bus. Designers can select the different methods for the determination of the communication architecture respect to various factors. In this study the architecture of station bus and process bus are presented based on the significance index of substations. The significance index of the substation is based on seven factors consist of substation capacity, the number of the transformers, substation configuration, number of feeders, location of substation in power network (ring or radial) and substation importance in power network and operation functions.

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