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RESEARCH ARTICLE

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Segment Design of Foundation Fieldbus

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ABSTRACT
In this paper segment design of communication protocol, foundation fieldbus is given from the view of power requirements, number of devices to be connected and the maximum length. Its multifunctionality, fast processing and consistency enhanced the industrial application of foundation fieldbus. Designing, engineering, configuration and implementation for a project of Oil & gas industry is practically proven. Consistent design methodology simplifies the implementation of the project.
Keywords: Field buses, communication protocol, High Power Trunk, control system, power supply, Macrocycle.

I. INTRODUCTION

Foundation Fieldbus is modern communication protocol used in Oil& gas, petrochemical industries as an enhancement to traditional 4-20 mA and HART (Highway Addressable Remote Transducer) designs. It is commonly used in intelligent measurements and control system with multidrop, digital, two way communication links. Fieldbus is a Local Area Network with single wire pair for powering multiple devices and carrying signals between those devices. It is available to all parties hence it is an open-network. The technology is based on International Electrotechnical Commission (IEC) and International Society of Automation (ISA).

Theoretically maximum field devices that can be connected in a segment is 32 but recommended are only 12 devices including spares. Devices are placed on segment based on location, control function and reliability requirements. Segment allocation is critical for the project success and is based on project Functional Design Specifications (FDS). Functional Design specification defines the hazardous area concept, components included, control strategy. [5]

Foundation Fieldbus architecture has two networks, H1 bus system and HSE (High Speed Ethernet) layer.

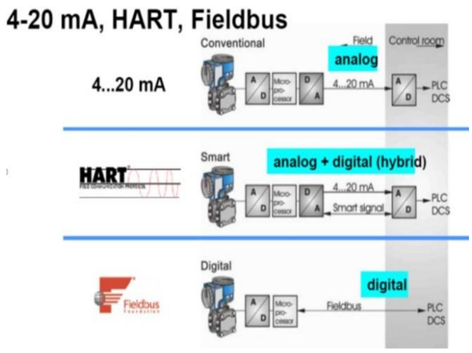

Fig.1. Comparison of conventional and fieldbus communication

II. FOUNDATION FIELDBUS TECHNOLOGY

Foundation Fieldbus model consists of three parts: physical layer, communication stack and user application. The physical layer receives messages from the communication layer, transmits to physical wire as electrical signals and vice-versa. The Data Link Layer (DLL) controls transmission of messages onto the fieldbus. Communication on the bus is controlled by Link Active Scheduler. User Application layer has defined standard functional blocks which are configured in the devices. For proper control system operation functional blocks must execute at defined intervals and in the proper sequence.

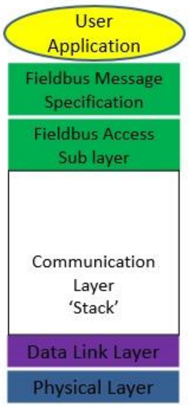

Fig.2. Fieldbus model

III. TOPOLOGY

Topology defines the shape of the network. Design consideration begins with the topology. There are mainly four topologies for Foundation fieldbus. They are: point to Point, Tree, Spur, and Combined. [9]

Fig.3. point- to – point topology

Point-to-point topology consists of only two devices hence not an economical design.

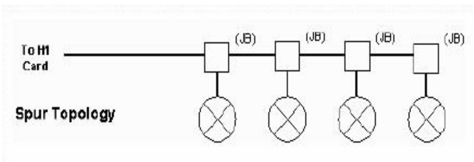

Fig.4. spur topology

In spur topology field instruments in segment are connected across the cable called spur. Economic feasibility is less.

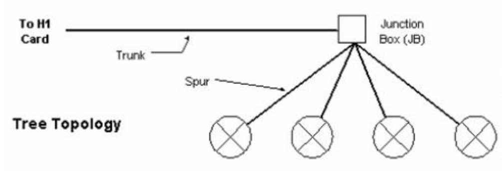

Fig.5. Tree topology

Tree or chicken foot topology is recommended one in which field instruments in a segment is connected to a junction box to form a network

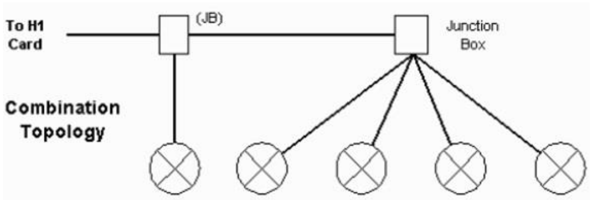

Fig.6. Combined topology

Total cable length is the combination of spur and trunk lengths

IV. COMPONENTS OF FF SEGMENT

IEC 61158-2 specifies the components that create a segment are fieldbus power supply, terminator and field devices. A DC power supply and a Fieldbus Power Supply provide power to the Fieldbus segment. A segment is terminated by two terminators at both ends. [9]

Host/Master- It resides in the control system Interface module. For Foundation fieldbus Interface is H1 host which is responsible for controlling and communication of the segment.

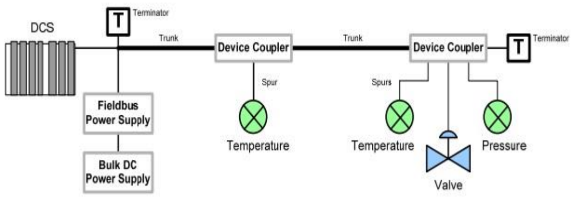

Fig.7. Fieldbus Segment

Trunk- Trunk is similar to tree trunk where all the branches are connected to the main branch. Trunk runs along the whole segment to which all the components (transducers, valves etc) are connected.

Spur- Spur cable connects the field devices to the trunk cable through a device coupler (Junction Box). The recommended spur length is 120m.

Terminator- A Terminator (T) is required at each end of the segment to avoid distorting signals. Terminators are often included in Fieldbus Power Supplies and Device Couplers, which eliminate the separate terminators. A terminator is a series combination of 1 μF and 100 Ω.

Fieldbus Power supply- Fieldbus Power Supply which has matching impedance to the segment, provide power to the field devices. The Fieldbus Power Supply is normally installed near the control room but could also be located in the field or in a marshaling panel. Output of power supply ranges between 12 V DC to 30 V DC and 110 mA to

500 mA. Redundancy is also an important characteristic which increase the reliability.

V. PHYSICAL LAYER CONCEPTS

Explosion protection for Fieldbus segments are High Power trunk and FISCO.

FISCO stands for Fieldbus Intrinsically Safe Concept and are used in Div1/ Zone 1 area which is documented in IEC 60079-27. In this concept the segment is protected by a FISCO power supply which limits the energy. Hence the number of devices in a segment is reduced. [10]

FNICO stands for Fieldbus Non-Incendive COncept, limited to zone 2 area. The output energy is limited such that in the presence of an hazardous situation a short, open, or grounding of the wiring will not cause an ignition. The entire segment is energy limited. Due to low energy level cable length will be shorter and less number of field devices will be connected in the segment.

HPT stands for High Power Trunk. From the name itself it is clear that Trunk carries high amount of power. It is widely used in Div2/ Zone 2 hazardous area. The main advantage is that number of field devices in the segment is not limited due to high power capability, Instead current limitation is given in device coupler which reduce the flow of energy to the spur and to field devices. Current limiting in Junction box is provided by safety barriers.

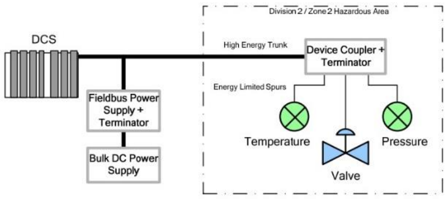

Fig.8. High Energy Trunk (Div 1 / Zone 1)

VI. MACROCYCLE

Macrocycle define the time taken for all the communication to be executed. All Scheduled messages are communicated in a macrocycle and the remaining time in a macro cycle is to communicate unscheduled messages.

The combination of scheduled and unscheduled communication completes a macrocycle time. Regular cyclic communication between control system and the field devices are performed through scheduled messages. The Link Active Scheduler (LAS) is responsible for scheduling a macrocycle. Token passing is provided by LAS of Data Link Layer. A compel Data(CD) is released by LAS and transmit a periodic data to a device in the segment which then 'publishes' or 'broadcast' the data in a buffer to all other devices. The device that receives the data is 'Subscriber'.CD returns back to LAS after passing the data.

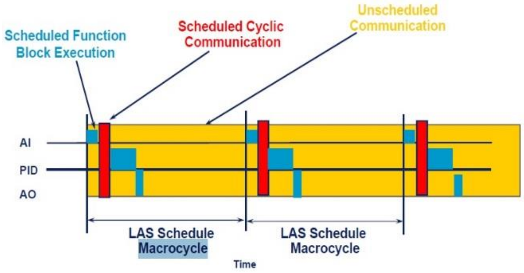

Fig.9 Functional Block scheduling

Unscheduled datas are user initiated which are sudden set point changes, tuning changes etc. LAS is permitted to issue Pass Token (PT) according to priority. When a device receives PT, it is allowed to send message until that is finished which is of short duration. [4]

VII. SEGMENT DESIGN CONSTRAINTS

IEC 61158-2 describes the requirements for planning and designing the segments for foundation fieldbus. Certain constraints are: Fieldbus type (HPT, FISCO, FNICO), Voltage drop calculation according to the cable type and the location, Current calculation, segment criticality rating and spare capacity of 25 %.[6]

VIII. VOLTAGE DROP CALCULATION

When designing a segment it is important to know the available power supplied to connect the number of field devices. IEC 61158-1 specifies the minimum and the maximum voltage required at the field devices. Hence the minimum operating voltage is 9V and the maximum bus voltage is 32 V. The main parameters needed to calculate the voltage drop along fieldbus cable is the number of devices, resistance of the cable, cable length and the current consumption. The current rating of field device is obtained from the Instrument Datasheet and usually it is between 10 mA to 30 mA. The IEC/ISA physical layer recommended cable is type "A" (Individually shielded twisted pair) fieldbus cable for which has a resistance of 44Ω/Km and a maximum segment length of 1900m. [3] To find how many instruments can be connected in a segment, the maximum current rating of field Instruments, resistance according to the length and the supply voltage is to be considered. Basic Ohms Law is applied to find the voltage drop across the segment and available voltage remaining. The minimum operating voltage should be 9V for each instrument even at the farthest end. In tree topology all instruments are connected in parallel fashion, thus available voltage at farthest device is only required to be calculated. [6]

Loop requiring macrocycle of 1 sec can have 12 devices with maximum 3 control valves. Loop of 0.5 sec macrocycle can have 6 devices with maximum 2 control valves. Loop of 0.25 sec macrocycle can have only 3 devices with one control valve maximum.

IX. SEGMENT CALCULATION

After collecting all the datas form the criterias, they are entered into foundation fieldbus DesignMATE for planning, validating and documenting Foundation Fieldbus H1. It automatically audits according to IEC 61158-2. It checks the parameters: supply voltage, load conditions, spur length and also obtain the power consumptions and short circuit possibilities.

X. VALIDATION AND RESULT

Cable Length: Segment, Spur, Trunk

L segment = L spur+ L trunk

Load Condition of Power supply

I segment = I Device + I Host + I segment protectors

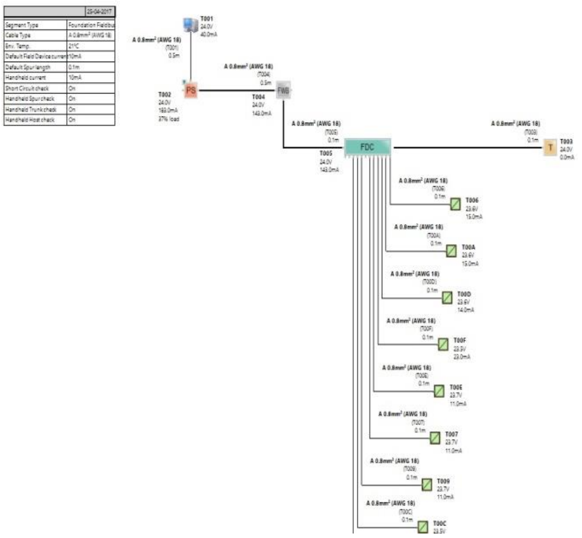

Fig. 10 Topology and validated segment

1) Calculations of validation

Power Distribution Check

	Current [mA]		Voltage [V]		
Tag	**must**	**is**	**must**	**is**	**Result**
T001	40.0	40.0	9.000	23.999	success
T002	143.0	183.0	9.464	24.000	success
T002:Output	143.0	143.0	9.464	24.000	
T002:Master Con.	40.0	40.0	9.001	24.000	
T004	143.0	143.0	9.461	23.997	success
T004:Spur 1	143.0	143.0	9.461	23.997	
T005	143.0	143.0	9.460	23.996	success
T005:Output	0.0	0.0	0.000	23.996	
T005:Spur 1	11.0	11.0	9.000	23.705	
T005:Spur 2	23.0	23.0	9.000	23.465	
T005:Spur 3	11.0	11.0	9.000	23.705	
T005:Spur 5	11.0	11.0	9.000	23.705	
T005:Spur 6	11.0	11.0	9.000	23.705	
T005:Spur 7	14.0	14.0	9.000	23.645	
T005:Spur 8	23.0	23.0	9.000	23.465	
T005:Spur 9	15.0	15.0	9.000	23.625	
T005:Spur 12	15.0	15.0	9.000	23.625	
T009	11.0	11.0	9.000	23.705	success
T00C	23.0	23.0	9.000	23.464	success
T008	11.0	11.0	9.000	23.705	success
T007	11.0	11.0	9.000	23.705	success
T00E	11.0	11.0	9.000	23.705	success
T00D	14.0	14.0	9.000	23.645	success
T00F	23.0	23.0	9.000	23.464	success
T00A	15.0	15.0	9.000	23.625	success
T006	15.0	15.0	9.000	23.625	success
T003	0.0	0.0	0.000	23.996	success

Summary:
Minimum applied voltage level for a device: 23.464V

Fig.11 Power distribution detail

Short Circuit Check

	Current [mA]		Voltage [V]		
Tag	**must**	**is**	**must**	**is**	**Result**
T001	40.0	40.0	9.000	23.999	success
T002	143.0	240.0	9.464	24.000	success
T002:Output	143.0	200.0	9.464	24.000	
T002:Master Con.	40.0	40.0	9.001	24.000	
T004	143.0	200.0	9.461	23.996	success
T004:Spur 1	143.0	200.0	9.461	23.996	
T005	143.0	200.0	9.460	23.995	success
T005:Output	0.0	0.0	0.000	23.995	
T005:Spur 1	11.0	11.0	9.000	23.703	
T005:Spur 2	23.0	23.0	9.000	23.463	
T005:Spur 3	11.0	11.0	9.000	23.703	
T005:Spur 5	11.0	11.0	9.000	23.703	
T005:Spur 6	11.0	11.0	9.000	23.703	
T005:Spur 7	14.0	14.0	9.000	23.643	
T005:Spur 8	23.0	23.0	9.000	23.463	
T005:Spur 9	15.0	15.0	9.000	23.623	
T005:Spur 12	15.0	15.0	9.000	23.623	
T009	11.0	11.0	9.000	23.703	success
T00C	23.0	23.0	9.000	23.463	success
T008	11.0	11.0	9.000	23.703	success
T007	11.0	11.0	9.000	23.703	success
T00E	11.0	11.0	9.000	23.703	success
T00D	14.0	14.0	9.000	23.643	success
T00F	23.0	23.0	9.000	23.463	success
T00A	15.0	15.0	9.000	23.623	success
T006	15.0	15.0	9.000	23.623	success
T003	0.0	0.0	0.000	23.995	success

Fig.12 short circuit check details

Table.1. Segment Current draws from FF Power Supply

Srl No.	Item	Value
1	Number of device per segment	9
2	Total current draw due to field devices	143mA
3	Current draw of FF termination block in JB	5mA
4	Short Circuit current	60 mA
5	Current draw of diagnostic tool	20mA
6	Current draw of H1 interface card	40mA
7	Total anticipated current from the FF power supply for segment of interest	268mA

Table.2 Voltage at field JB

Srl No.	Item	Value
1	Voltage present at H1 card	24V DC
2	Cable Electric Specification (Belden 3076F)	21.8 Ω/km
3	Length of home run cable	525
4	Total wire length of segment (2 x length)	1050
5	Total resistance of segment home run	23.1
6	Current draw of field side downstream of H1 card	268mA
7	Total voltage drop on home run cable	6.19 V
8	Voltage available at FF terminal block in field JB	17.81 V

Table.3 Voltage available at the device on the longest Spur

Srl No.	Item	Value
1	Voltage present at field JB	17.8
2	Cable Electric Specification (Belden 3076F)	21.8 Ω/km
3	Length of longest spur	85
4	Total wire length of spur (2 x length)	170
5	Total resistance of spur	3.74
6	Current draw of the field device	15Ma
7	Current draw of diagnostic tool	20 Ma
8	Total current draw of the spur	35mA
9	Voltage drop due to spur cable resistance and spur load	1.3 V
10	Voltage available at the field device (including use of diagnostic tool)	22.7 V

XI. CONCLUSION

Foundation Fieldbus is widely used in industrial plants either brownfield or Greenfield is because of the interoperability. Faster Execution and simplified architecture in hazardous area boost up the demand of FF in the market. Application of foundation fieldbus is spread over petrochemical, Oil & Gas, mining & metal, food & beverages recently added to safety Instrumented systems.

The digital communication is more fault tolerant and multiple process parameters can be transmitted by encoding. Diagnostic tools that can be incorporated with a segment make a faster maintenance method.

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