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TRANSFORMER TAP CHANGER USING IEC61850

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Abstract- Traditionally, protection and control Systems were separate applications, with different technology and operation. Today both functions can be integrated in a single IED(Intelligent Electronic Device), being at once, Substation automation has traditionally been a business with Long time frames and a conservative approach regarding Technological advances. Primary equipment in the Substations has a typical life span of 30 to 50 years, and Upgrades on the secondary equipment have often been Forced to follow almost the same cycle. In addition communication network technology has developed fast over the past years, enabling a more centralized control. This all has led to an increasing need to gather data from larger networks. One example of this discussion is voltage regulation with tap changer.A tap changer control operates to connect appropriate tap position of winding in power transformers to maintain correct voltage level in the power transmission and distribution system. [2]
In this paper the authors describe conventional tap changer and development in transformer tap changer control using IEC61850.
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Keywords: Voltage regulation, Tap-Changer, Transformer Bay, IEC61850, Object Oriented Model.

I. INTRODUCTION

Most of the transformers in power transmission and distribution system operate in parallel, so failure in one of them, the total electrical load in demand is transferred to the other transformers operating in parallel. Automatic tap-changer control of transformers is used to maintain the voltage level of electric supply in the transmission and distribution system and also controls the power sharing among parallel transformers. In the parallel operation, the existing tap-changer controls of transformers have many limitations and complexities. For example none of the existing controls can be used when parallel transformers are connected across the network, i.e., their primaries are connected to different sections of a complex power network. The use of a huge number of relays in some of the existing control circuit causes disruption in parallel operation for a minor fault until technicians fix it. Since the failure rate of relays is high, such fault may occur frequently. Some control systems are incapable of parallel operation of more than two transformers and others operate well only if the load power factor is near to unity but fails to function properly if the power factor deviates far from unity . Here discos conventional tap changer control and new method like fuzzy and ANN based IEC61850 communication protocol. [13]

II. CONVETIONAL TAP CHANGER

An important aspect of operating power transformers is being able to vary the ratio. This is done to match the voltage if the load fluctuates, to distribute load, to adjust active and reactive currents in interconnected system and for voltage matching purposes with electric furnaces and rectifiers.

To obtain specified voltage on the output side, the transformer's high-voltage winding is provided with tapings (main and control winding) which are connected in different sequences according to the load. The respective winding sections are selected by means of off-load or on-load tap changer.

Off-load tap changer are used in networks with little fluctuation in load and On-load tap changers are used in network with frequent brief load fluctuations.

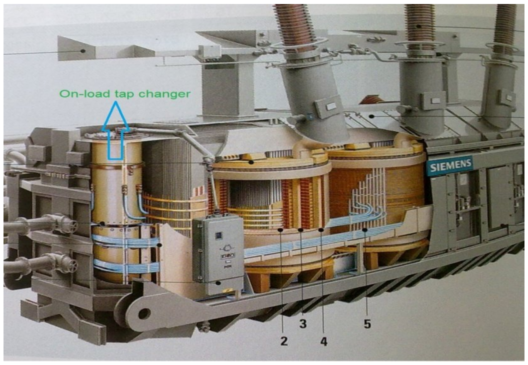

Figure 1 on load Tap changer

Tap changers are mechanically driven – via the drive shafts and the bevel gear–by a motor drive attached to the transformer tank (see figure 1). It is controlled according to the step-by -step principle. Electrical and mechanical safety devices prevent over running of the end position. Further safety measures, such as the automatic restart function, a safety circuit to prevent false phase sequence and running through position, ensure the reliable operation of motor drives. [12, 8, 14]

The tap changer can be actuated directly at the transformers with aid of a crank handle (emerge operation). Electrical local control by pushbutton is also possible. In this case, switching from one tap to another requires a separate command so that a single command cannot be execute more than one change.(see figure 2)

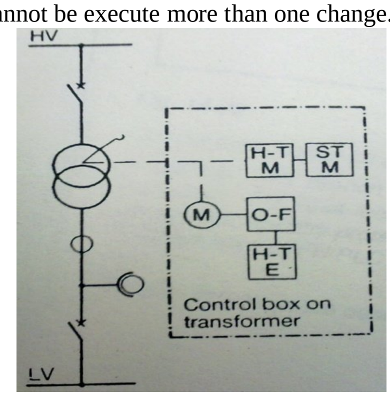

Figure 2 Local control

Electrical control is also possible from the station control room or the network command center (see figure 3 and 4). Simultaneous actuation from the three locations is prevented by selector switches. A pilot light on the station panel stay on while taps are being changed, indicating that a control command is being executed.

Remote indication of tap setting can be provided by a contact strip with resistor (e. g. 3 ohm per tap) on the changer operating mechanism, together with a DC voltage source (e. g. 6 V power adaptor) and scale instrument showing the tapping number .The station panel can also show the voltage to be maintained, as well as the selected tapping.

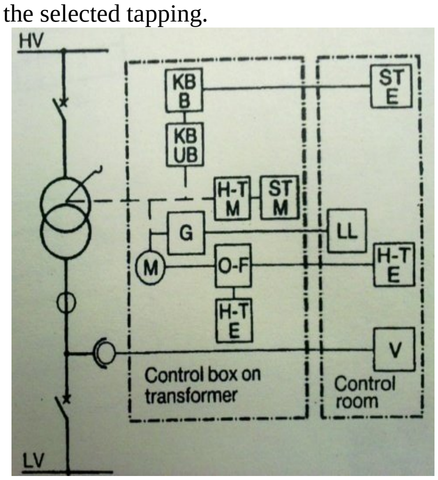

Figure 3 Station control

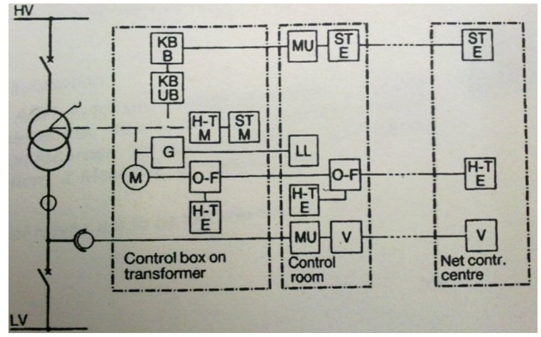

Figure 4 Remote control

Where several transformers are connected in parallel, the tapping must have an interlock system which is active only in parallel operation. The interlock prevents different tap setting on paralleled transformers from giving rise to an excessive reactive current witch could damage the transformers.

The controller of only one transformer, the master transformer, should be active when running in parallel (see figure 5). This master controller, specified by means of the selector switch, then acts on tap setting of all the transformers connected in parallel.

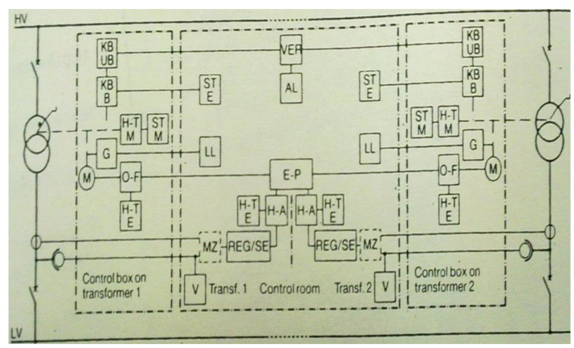

Figure 5 Parallel transformer

III. TAP CHANGER CONTROL BASED IEC61850

Substation Automation Systems (SASs) are widely used for the purpose of control, protection, monitoring, communication etc. in substations to improve the reliability of the power system.

SASs adopting IT based solutions such as Ethernet LAN has recently become more common, although hardwired control has been used in the past in earlier versions of SAS utilizing simple communication methods. Moreover, the IEC61850 standard has been issued as the new global communication standard for substations. The standard consists of ten parts, the final part being issued in 2005. Subsequently IEC61850 has been applied widely in SASs around the world. The most important feature of this standard is related to Object Oriented model that describe in next part and then application of it for tap changer control.

A. Object oriented model

One physical device can be defined by one or many logical devices. Multiple logical devices are used to separate functions in single physical device, which Logical nodes are construct from data classes or data objects, each of which contains data attributes, See fig 6. The standard defines concepts and some rules for physical devices and for logical devices and Logical devices are defined by logical nodes. The logical nodes describe the functions and functional interfaces. A function may be constructed from multiple logical nodes and the logical nodes can be located in different physical devices. Then the function is called distributed, see fig 8 . The logical nodes are linked by logical connections, which are independent of the physical connections with the use of Ethernet solutions. [3, 11]

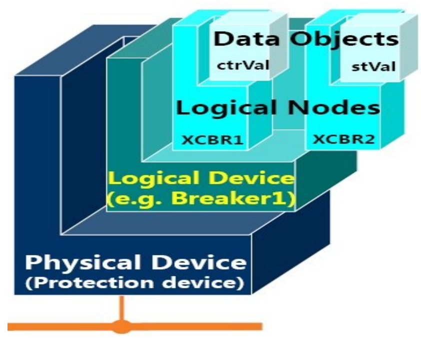

Figure 6 IEC61850 class mode

The standard defines rules for creating new logical nodes and common data classes. The rules for creating new objects have been defined to preserve interoperability.
The data point reference constructs like the IED is modeled but instead of an index number this reference that are understandable without additional decoding aid. Naming systems are universal and easy to understand with IEC 61850 standards. See fig 7.

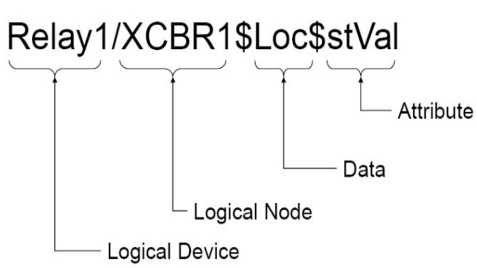

Figure 7 Object name structure

The logical node concept is in major role in the whole standard. The logical nodes are the basic objects that exchange information and the “backbone” to model real devices. The logical nodes contain some mandatory predefined sets of data objects with specific data attributes. All these concepts have a logical structures and strong semantics related to real substation automation devices and tasks. The information contained in logical nodes is exchanged by services with well-defined rules and performance requirements.

B. Distributed function

IEC 61850 standard has been created to be functionally flexible and expandable. See fig 8.

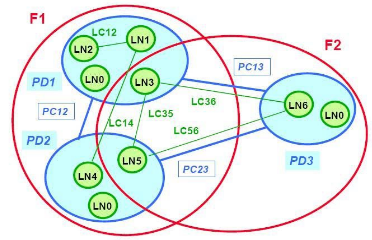

Figure 8 flexible functionality of LNs in different IEDs

It uses communication information technology, which support variety of services with selection of performance requirements with Fast communication between individual IEDs that enables bay to bay communication. With bay to bay communication for example interlocking function can be executed trough communication lines. So with IEC 61850 IEDs can communicate with each others, by publishing and subscribing Generic Object Oriented Substation Event (GOOSE) messages. And also this message can increase reliability which discuss in reference [5]. Utilization of Object Oriented model improves functionality of system because with GOOSE messages and horizontal communication, the information is accessible over the substation from different IEDs. [11]

In our case when a function requires exchange of data between two or more logical nodes located in different physical devices, it is called a "distributed function". Voltage regulation function is based on sample value that measured by voltage transformer.

Distributed functions based on sampled analog values are achieved by using one group of devices that perform analog interface with the primary substation equipment and another set of devices that process the communicated sampled measured values in order to achieve the desired substation function.

The exchange of data is not only between functional elements, but also between different levelsof the substation functional hierarchy figure 10 shows different levels in voltage regulation function (tap-changer). It should be kept in mind that functions at different levels of the functional hierarchy can be located in the same physical device, and at the same time different physical devices can be exchanging data at the same functional level.

The allocation of functions between different physical devices defines the requirements for the physical interfaces, and in some cases may be implemented into more than one physical LANs.

These control applications are built around the transformer in the substation. Figure 9 shows a power transformer along with the breaker, CT, PT breaker and OLTC. This transformer is protected by a single IED with multiple protection and control functions. Layout of the logical nodes, physical device and interconnections for a transformer bay is shown in Figure9.

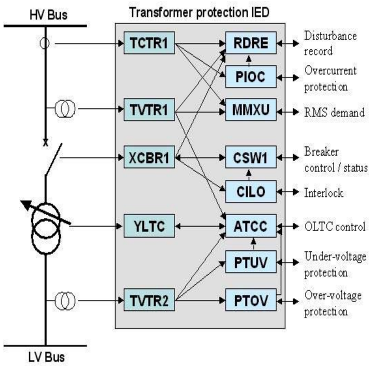

Figure 9 Transformer bay

The target is to maintain the voltage at the LV (Low Voltage) bus at the rated value. This is an implementation of an automatic control task. The position of the OLTC (on-load tap changer) is calculated based on the voltage at the load bus. To make it more adaptive the present amount of load can also be taken into consideration. [4]

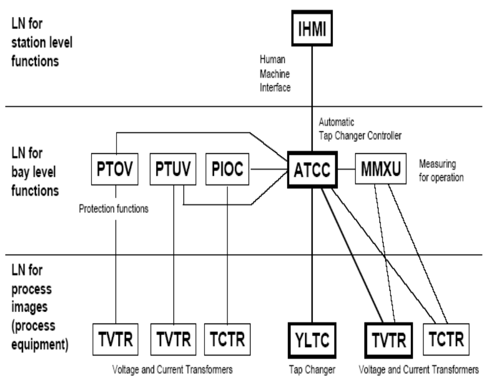

Figure 10 LN in different level

The logical nodes involved in achieving this function are shown in figure 10. The node "IHMI" is physically present in the master PC of the operator. This node is assigned in this application to provide the status information to the operator. The logical nodes PTOV (over-voltage protection), PTUV (under-voltage protection), PIOC (over-current protection), ATCC (automatic tap change control), MMXU (measuring process) are present inside the IED. The logical nodes TVTR1 and TVTR2 (voltage transformers), TCTR (current transformer), XCBR (circuit breaker), YLTC (tap changer) are also housed in the IED. However it is possible to have had these nodes external to the main IED when the concerned primary equipment has communication capability. The connection between the logical nodes is implemented using logical connections.

When the bus voltage goes below (or above) a threshold set in the ATCC logical node, it decides to increase (or decrease) the tap. This decision also depends on the status of the protection elements (they should not have operated) and the power flow. It also calculates the number of taps to be raised (or lowered). This information is then given to the YLTC through the logical connection. The YLTC node in turn gives pulses to the OLTC control motor to change the tap position. The YLTC returns the present position of the tap to the ATCC node. For implementing this application a low speed data transfer is sufficient (500ms) [1].

C. Parallel transformer tap changer based IEC61850 communication

Each voltage control block will send the same dataset, but each voltage control block (or more specifically each IED containing a voltage control block) will have unique address definitions for the GOOSE control block. This will ensure that data is unique within inter bay bus. To receive this dataset from the other transformers, the voltage control function must subscribe to the GOOSE messages sent by other IEDs in the system. Subscribing to these GOOSE messages will enable the voltage control function to operate in parallel utilizing the data from the other transformers.

The parallel function should consider only GOOSE messages from the voltage control functions working in parallel (i.e. according to the current station configuration or setting parameter). The status of isolators and circuit breakers in the station (station configuration or topology) are of vital importance since the connected state (i.e. parallel, disconnected etc.) of the transformer depends on these devices. The station configuration information can also be received via GOOSE, and subscribed to, enabling the voltage control functions to determine its connected state and control accordingly. In order for the voltage control functions to subscribe to the station topology information, the isolator and circuit breaker statuses need to be transmitted via GOOSE from the device where the information is wired to. This could typically be a bay control IED in the substation automation system. This bay control IED would contain a GOOSE control block with associated datasets containing XCBR, XSWI and CSWI information which the voltage control function could subscribe to. Automatic control is automatically blocked if the horizontal GOOSE communication for any one of the voltage control functions in the parallel group fails (all voltage control functions which belong to the same parallel group will be blocked).

IV. FUZZY CONTROL IN TAP CHANGER

Fuzzy control theory has been applied to voltage regulator after analyzing the existing questions of conventional some area control method..[6, 7]

A. Input and output

The input and output of voltage fuzzy as follows. Input I: voltage deviation field is [-4, 4] and its language values are NB, NS, 0, PS, PB, expressing negative big, negative small, normal, positive small, positive big separately. Input II: tap position field is [-4, 4] and its language values are DOWN, NOR, HIGH, expressing low, normal, high separately. Output I: tap control field is [-4, 4] and its language values are DOWN, NO, UP, expressing decrease, no move, increase separately. Output II: inverse time field is [0, 60] and its language values are S, N, L, expressing shot, middle, long separately. The input and output of reactive power fuzzy control as follows. Input I: reactive power deviation field is [-4, 4] and its language values are NB, NS, 0, PS, PB, expressing negative big, negative small, normal, positive small, positive big separately. Input II: capacitor status field is [-4, 4] and its language values are N, 0, P, expressing few, normal, many separately. Output I: capacitor switch field is [-4, 4] and its language values are DOWN, NO, UP, expressing switch off, no switch, switch in separately. Output II: inverse time field is [0, 60] and its language values are S, N, L, expressing shot, middle, long separately. [7, 9, 10]

B. Fuzzy Control Rules

On the basis of control theory and corresponding rules of power system, the fuzzy control modules of voltage which is showed in Table1 is gained generalizing from the operation experience.

Table 1 Fuzzy rules

F U KF/TF	P B	P S	O	N S	N B
DOWN	UP/S	UP/N	NO/L	NO/N	DOWN/S
NOR	UP/S	UP/N	NO/L	DOWN/N	DOWN/S
HIGH	UP/S	UP/N	NO/L	DOWN/N	DOWN/S

C. Implant fuzzy controller to system

The fuzzy controller placed before voltage regulator relay and send proper signal to it for changing the transformer tap. (See figure 11 and 12)

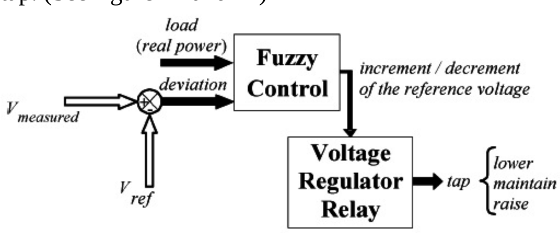

Figure 11 fuzzy controller

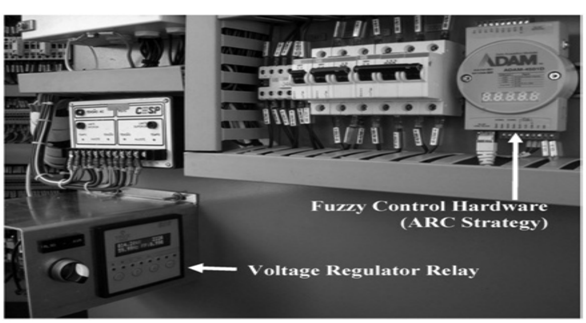

Figure 12 real fuzzy controller in substation

V. IMPLEMENTATION OF ANN BASEDTAP CHANGER CONTROL

An interface between the power system and the ANN (Artificial Neural Network) based control system is described. A number of implementation strategies for the ANN tap changer control and their integration with the existing power system components have been outlined.

At the hardware level design outlines for implementing the ANN tap changer control on a single semiconductor chip and on a microprocessor unit are presented. Two strategies have been suggested to implement the ANN tap changer control as a software module. One is to integrate it with the supervisory system in a substation control room operating in a LAN environment. In this configuration, the parallel transformers can be controlled locally. The other is to integrate it into the SCADA system, which allows the transformers to be monitored and controlled remotely over a wide area of power network.

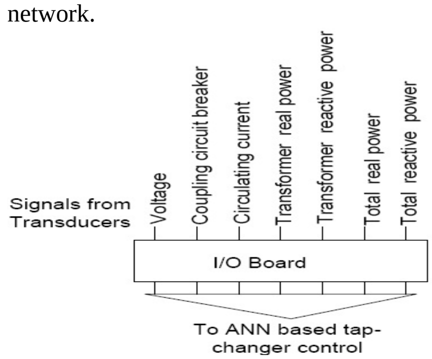

Figure 13 ANN Based tap changer

VI. CONCLUSIONS

With the development of modern technology, especially in the areas of microprocessor and control, the performance of the protection relays and control function have been significantly improved. Control and protection of transformer bay isn't exceptional, and it improves and developed too.

In IEC61850 all information from transformer bay virtualizes into LNs that are accessible anywhere in substation and it is possible to utilize new method for control and protect function like Fuzzy Logic Controller and ANN in substation

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BIOGRAPHIES

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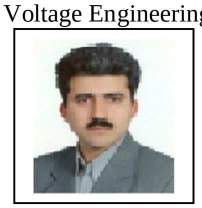

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