A Design of Intelligent controller for controlled switching of circuit Breaker

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ABSTRACT - *Circuit breaker is one of the most critical elements of power industry. Controlled switching of grid voltage and grid current is the best solution to prevent the high inrush current and over voltages. Controlled switching of circuit breaker can be implemented by using processor based architecture. With this architecture early detection of most of major fault is feasible. It is also possible to monitor most the critical parts which affect the contacts of circuit breaker with single system. Controlled switching device is developed using Arm controller and DSP (Digital signal processing) system. Controlled switching of circuit breaker provides significant technical and economic benefits, including enhancement of power quality and operational flexibility. It could be incorporated into circuit breaker control systems as a standard specification in the near future. The developed system includes features such as oscillographic data storage, real time fault analysis, event information and alarm. Future trend of a controller can be used to store monitoring results which can be used for remote diagnostic and condition based maintenance in order to improve equipment reliability and optimized maintenance practices.*

*Keywords:*Intelligent controller, controlled switching

I. INTRODUCTION

The modern power system deals with huge power network and huge numbers of associated electrical equipment During short circuit fault or any other types of electrical fault this equipment as well as the power network suffer a high stress of fault current in them which may damage the equipment and networks permanently. for saving these equipment and the power networks the fault current should be cleared, the system must come to its normal working condition as soon as possible for supplying reliable quality power to the receiving ends. In addition to that for proper controlling of power system, different switching operations are required to be performed so for timely disconnecting and reconnecting different parts of power system network for protection and control, there must e some special type of switching devices which can be operated safely under huge current carrying condition. During interruption of huge current there would be large arcing in between switching contacts, so care should be taken to quench these arcs in circuit breaker in safe manner. The circuit breaker is the special device which does all the required switching operations during current carrying condition.

The magnitude of transient depends upon the instant on the voltage waveform where opening or closing of breaker contacts occur. In an uncontrolled situation, sooner or later switching is bound to occur at the worst possible points-on-wave. Conventional methods used to limit the magnitude of these switching transients like Pre-insertion resistors, Damping Reactors, Arrestors or upgrading the insulation are inefficient, unreliable or expensive and do not address the root problem Sooner or Later, uncontrolled switching is bound to occur at the worst possible points on wave.

2. Design of Proposed System Development

For accurate performance of a Controller it is vital to develop a system with the point to point testing. This chapter briefs about proposed system and flow chart which is followed by controlled switching of a circuit breaker with the help of a controller.

Basics of Proposed System:

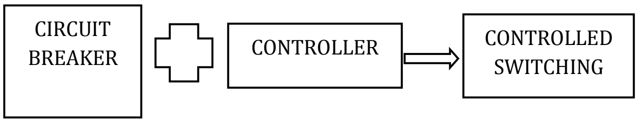

Fig 1.Proposed System

Proposed system gives controlled switching of circuit breaker with the help of intelligent controller. Our aim is to design a intelligent controller of a circuit breaker which is suitable for power system to prevent the high inrush Current and over voltage.

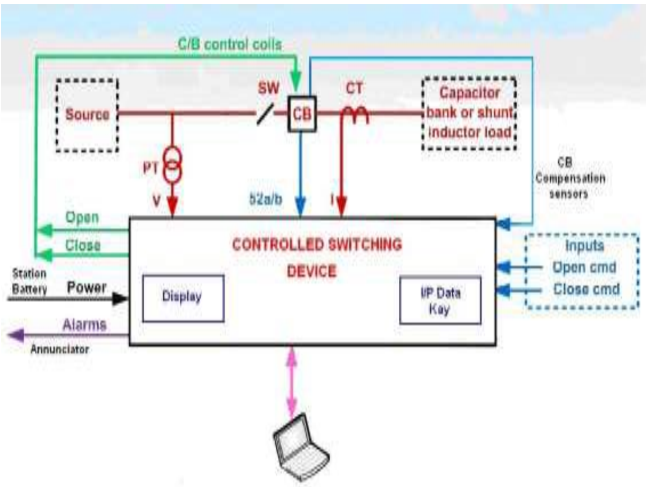

Fig 2. Block Diagram of proposed system

2.1 .CONTROLLED CLOSING

Controlled closing refers to controlling the point of conduction of each pole of the breaker with respect to the phase angle of the voltage. Breakers used in these applications must be constructed to provide the consistency to successfully repeat the controlled closing operations. The controller monitors the source voltage for a controlled closing operation.

The closing command is issued randomly with respect to the phase angle of the reference signal at some instant, as shown in Figure. The controller delays the randomly received closing command by some time, Total time, which is the sum of mechanical closing time (Tc) of the circuit breaker and an intentional synchronizing time delay.

2.2. CONTROLLED OPENING

Controlled opening refers to controlling the contact separation of each circuit breaker pole with respect to the phase angle of the current. Controlling the point of contact separation determines the arcing time of the contacts to help prevent breaker and circuit switcher failures and to minimize stress and disturbances to the power system. The implementation of controlled opening is approximately the same regardless of the equipment being switched. The control is straightforward once timing data for a breaker is available, particularly the time from energizing the trip coil to contact separation. Although controlled opening is best done using the current through the breaker, the bus voltage can be used if the voltage current phase relationship is always known, such as for shunt reactor and shunt capacitor switching. The breaker is controlled so that its contacts will part just after a current zero. As the contacts continue to open they draw out an arc that will extinguish less than a half cycle later at the next current zero. When the arc does extinguish, the contacts have been separated as far apart as practical, which provides the maximum dielectric strength available for the circumstances. This gives the breaker its best chance of successfully withstanding the recovery voltage and not having a re-ignition or a re-strike. Re-ignition is a dielectric breakdown that re-establishes current within 90 electrical degrees of interruption. Re-strike is a dielectric breakdown after 90 degrees. Figure shows the timing sequence for controlled opening. The control command is issued randomly with respect to the phase angle of the reference signal at an instant.

The randomly received opening command is delayed by the controller by some time, Total time, which is the sum of mechanical opening time of circuit breaker and an intentional synchronizing time delay (waiting time), synchronizing time is calculated with respect to a relevant zero crossing which is a function of the opening time (Tz) and waiting time (Tw), The mechanical opening time, is the time interval from energization of the breaker trip coil to the start of breaker contact separation,

3. SYSTEM CONSIDERATIONS

3.1. Principle of Controlled Switching

There are several important circuit breaker applications where random closing instant may lead to severe voltage switching transients and random opening instant may lead to severe current switching transients, as in circuit breaker closing take the voltage reference and opening take the current reference.The switching transients that occur during the switching of capacitive and inductive loads result in thermal and dielectric stress on the connected equipment in the system, the intensity of the switching transients during switching operations depends on the phase position at the point of switching.

3.2 Architecture of Intelligent Controller

Each module contains 16-bit microcontroller and various signal conditioning circuits as shown in figure.

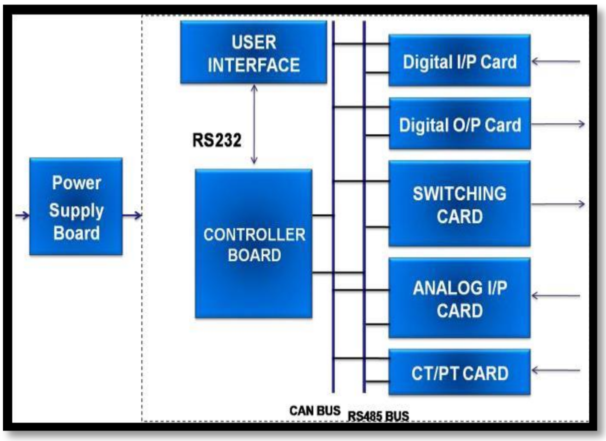

Fig 3.Block Diagram of Architecture of Intelligent controller

Every card has its own microcontroller dsPIC33Fxx which prevents the central processing card from overloading by the inputs as all the data is first processed by their own controller and then the information is sent to the central processing card. One of the advantages of using multi-processor architecture is that each controller is performing a low level task, time stamping and the necessary signal conditioning part for the input channels. Operating temperature of each module is from -20°C to +60°C.

Each module provides 2.5kV isolation to the input signal and 1kV isolation for the communication interface. All the modules are powered by a single 12Vdc power supply; there is an internal dc-dc converter in each module that generates the required voltage (3.3V@ 0.8A) for controller and other peripherals. This system has many interfaces to communicate with external world such as Rs232, Rs485, USB-device, and RJ45. It also supports IEC 61850 protocol. Implementation of this standard protocol makes the system ideal to interface with substation softwares such as SCADA & DMS which makes it suitable for controlled switching of Circuit Breaker. All the Events and oscillograms of R, Y, B phase grid voltage and grid current are recorded internally inside the Flash memory. This feature enables various users to view the events and oscillograms to be used for further analysis.

c. Different Modules in Controller

i.Digital Input Card :Digital input card (DIC) is used to acquire various digital inputs from contactors/actuators like status of air pressure, close command, open command, auxiliary switch position feedback, and auto-reclosure. Digital input card have 16 digital inputs in one module. It is designed to work within the operating input range of 20Vdc to 220Vdc.

ii.Digital Output Card :Digital output card (DOC) is used to provide on/off commands to relays within the system. It is designed to simultaneously trigger at most of the ten relays . DO card gives the alarms like temporary over voltage, inrush current, contactor failure, operation failure, sensor failure, breaker opening, and breaker closing of RYB phase.

iii.Analog Input Card :Analog input card (AIC) has 16 isolated channels. it is used to take the input from various analog sensors such as SF6 pressure sensor, temperature sensor, air pressure transducers. The analog signals are converted to 4mA to 20mA current signal and digitized by controller. Controller sends the digitized signals to CPC card on CAN bus.

iv.SwitchingCard :Switching card (SWC) will amplify the power of switching pulse for closing and opening of main contact and auxiliary contact of the circuit Breaker. It has two analog channels to condition dc voltages from main and auxiliary batteries. The conditioned analog signals are digitized by controller and sent to CPC card on CAN bus.

v.DisplayCard :Display card is used to show the monitoring parameter of the circuit breaker like grid voltage, grid current, breaker status, various events and oscillograms of R, Y, and B phase. Factory settings can also be done by the user using the display card.

vi.Current Transformer / Voltage Transformer (CT/PT) Card :In this card measurement of grid voltage and grid current are done by taking proper ratio of current and voltage in software configuration. In this there are two types of CT/PT one is for metering called metering CT/PT and another is for protection called protection CT/PT.

vii.Power Supply Card :Power supply card (PSC) provides 12Vdc @5A to all the cards. Power supply card has the input range 60Vdc to 270Vdc.

viii.Central processing Card :Central processing card (CPC) is the brain of system. CPC is the multiprocessor card in which all the algorithms and decision making is done.

d.Design of CPC card

CPC is the multiprocessor card. It uses two processors both from Texas Instruments one is 450MHz ARM processor other is TMS320F2812. ARM processor is designed to work on the linux operating system while the TMS320F2812 works as a main controller in which all the algorithms and decision making is done.

4. FUNCTIONAL OPERATION OF CONTROLLER

Following tasks are performed by the system to monitoring and controlling the critical parts of the Circuit Breaker.

Acquire: In this task the data from all the sensors mounted on critical parts of the Circuit Breaker through analogue input card and CT/PT card.

Analyse: All the data received by input cards is then analysed by the central processing card. All the parameters are to be sent to LCD for display and all the inputs by the operator are received and manipulated to perform the desired action. The data captured by the acquire task is then analyse by various algorithms for controlled switching of the circuit breaker.

Control: After analysis of data by central processing card it is sent to digital output card and switching card to perform the control actions by relays and Power MOSFETS / TRANSISTOR.

1. Store: The controller also keeps the historic data for computation purposes to understand the proper functionality of open and close operation of the circuit breaker.
2. Oscillograph and Events: In this 10 numbers of oscillograph (R Y B phase grid voltage and grid current) and 32 numbers of events can store in flash memory.
3. Communication: All the processed data is sent to the SCADA through IEC 61850 Protocol.
4. Adaptive Control: The main function of the adaptive control is to make a prediction of the circuit breaker time, execute the operation, monitor or record the actual circuit breaker operation time and use this value to correct the next operation.

5.TESTING PROCEDURE AND COMPENSATION FOR CIRCUIT BREAKER

The main function of the controller in this is to allow for point on wave, controlled switching of the breaker, using the voltage zero-crossings as reference for CLOSE operations and the current zero-crossings for OPEN operations. The timing of the respective phase signals takes into account the phase shift between phases, the observed operating times of each phase mechanism and the compensation for changes in operating times due to physical constraints (ambient temperature, SF6 gas pressure, air pressure, dc voltage for operating the breaker coils, etc.)The following compensations are made in the central processing card with the help of these compensations the target for closing and opening operation is achieved.

5.1 Coil Voltage Variation Compensation:

In Coil Voltage Variation Compensation, the coil voltage is varied The 4 points of “closing and opening times” are set during circuit breaker commissioning for R, Y and B phases. These timings will be according to the standard values of coil voltage and air pressure from the circuit breaker’s specification. “closing and opening times” will vary with line frequency also. If any of these 3 parameter changes, the corresponding waiting time is compensated in actual mechanical time. Following graph shows the close and open time against coil voltage variation for one pole with in accuracy of 1.0 mSec.

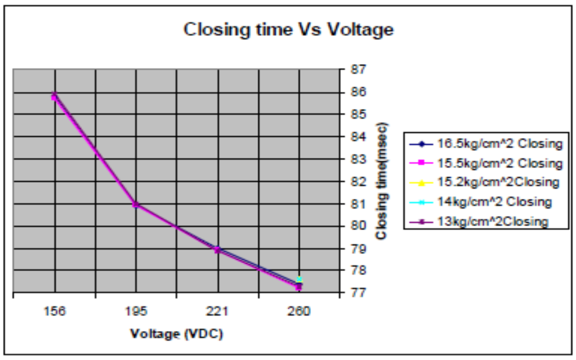

Fig. 4 Closing time Vs Voltage Graph

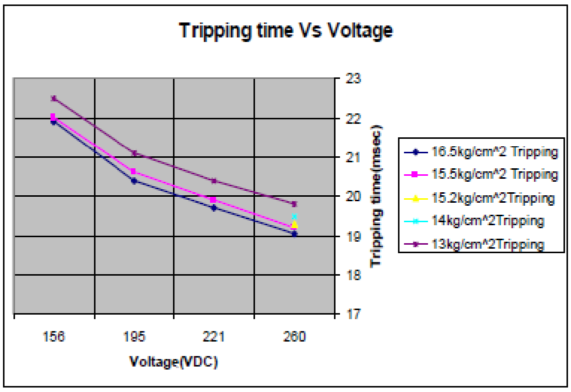

Fig. 5 Tripping Time Vs Voltage Graph

5.2 . Air Pressure Variation Compensation:

The closing and opening time is changed with respect to changes in air pressure. The variation of close and open time with respect to air pressure is compensated in the POWS. The following compensation curves (Figure 9 & 10) are implemented with-in 1.0 ms accuracy. For Calculating opening time at actual Air pressure(Ap) read tripping time(Tp1) at Air pressure(Ap1) and tripping time(Tp2) at Air pressure(Ap2) from HMI entered value then calculate tripping time(Tp) .

5.3 SF6 Gas Pressure Variation Compensation:

SF6 gas is the ideal media for the arc interruption and dielectric strength. This compensation comes in action during the closing operation; at close time SF6 gas rated pressure is 7 Kg/cm^2.

5.4. Idle Time Compensation:

Idle time compensation is used to compensate the predicted breaker operation time by taking into account the delay between operations of the circuit breaker. For some circuit breaker technology, an operation will be "quicker" if the previous operation was only a short while before compared to a "longer" time if the circuit breaker was idle for a long period. For this compensation to be effective, controller calculates the time between "now" and when the last operation was done. Of course, this values continuously increments each seconds but is being reset to zero after the completion of each operation.

6.CONCLUSION AND FUTURE WORK

In this paper a solution for point-on-wave controlled switching of circuit breakers are described. The operation of circuit breaker is operated on capacitive and inductive loads as well as unloaded transformers and transmission lines. The system automatically adjusts the circuit breaker operation according to the supply voltage, ambient temperature, drive mechanism pressure.

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