MODELLING AND ANALYSIS OF A UNIT PROTECTION

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Abstract
This paper presents a modelling and analysis of a unit protection of feeders. The protection system module is linked to the primary power system module in such a way that it acts as a feedback loop. The primary power system module provides the three-phase voltages and/or currents at the transducer locations. The protection system module is then processes this data, and outputs a circuit breaker status which can then be fedback into the primary power system module. The paper also describes the integrated dynamic power system model strategy.

I. Introduction

The function of an electrical power system is to generate and distribute electrical energy in most effective and efficient manner possible, while still providing the consumer with a secure supply. To allow these aims to be met, it is necessary to operate the plant involved towards the limits of its design capacity, while still ensuring a minimum disruption[1]. Protection is therefore applied to power systems in order to maintain the safe and economic operability of such systems. It should be noted however, that protection does not prevent faults from occurring on the system. It merely attempts to minimise the effects once a fault has developed. Most faults experienced in a power system occur on the lines connecting generating sources with usage points. Just as these circuits vary widely in their characteristics, configurations, lengths, and relative importance, so do their protection scheme[2]. The graded overcurrent systems though attractively simple in principle, do not meet all the protection requirements of a power system. Application difficulties are encountered for two reasons; first, satisfactory grading cannot always be arranged for a complex network and secondly, the grading settings may lead to maximum tripping times too long to prevent excessive disturbance of the power system.
In this paper, a simple power system with four protection units and the flow diagram of the integrated power system model is described. The relay modelling and its function is also explained.

II. Dynamic Power System Modelling Strategy

The proposed integrated dynamic power system model will be divided into two modules as follows:

1-) The primary power system module

2-) The protection system module
The protection system module is linked to the primary power system modules in such a way that it acts as a feedback loop as shown in Figure 1.

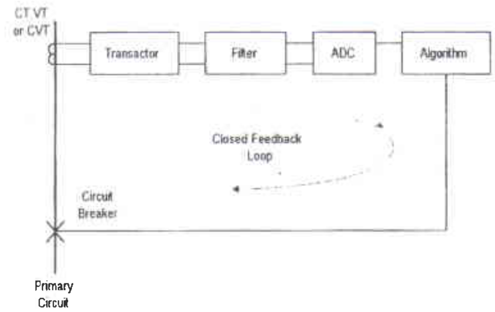

Figure 1: Integrated Dynamic Power System

In order to reduce the size and complexity of the code, it is thought appropriate that protection system models, eg. transducers etc., should be district from the historical data that is required for them to operate, eg. previous filter inputs and outputs for recursive filtering etc. This will allow each model code to be used repeatedly. To facilitate this separation of models and data, protection unit models, and associated protection unit records are being developed. Each protection unit model contains a model of a transducer, a relay, and a circuit breaker. However, the protection unit model contains models of two transducers, two relay units and communications between them and two circuit breakers. This is required to accommodate the pairing of this type of unit protection. Each protection unit record will store all the historical data required for its associated protection unit model to operate.

Figure 2 shows a simple power system protected by four protection units. Figure 3 shows the general data flow of the program structure. The primary power system module updates the protection unit records with the relevant three-phase voltages and/or currents. These records and the protection unit models then interact to output a circuit breaker status which is fedback to the primary power system module.

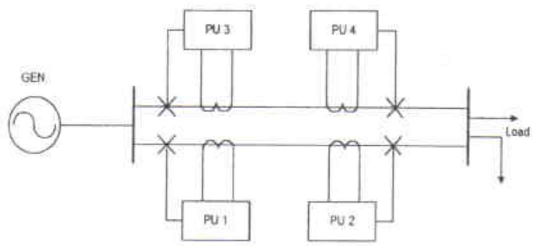

Figure 2: A Simple Power System with Four Protection Units

III. Primary Power System Module

The primary power system module is based on a three-phase coordinate model [3] of the test system which incorporates synchronous generation, complete with prime movers and controllers [4], generator transformer and network details. Symmetrical and asymmetrical disturbance conditions can be conveniently accomodated. The system is formulated in a modular manner consisting of individual subsystem configurations. Transducers together with their associated protection devices are interfaced to the main program again using a modular strategy.

IV. Transducer Modelling

Dynamic modelling of the protective current transformer has been developed for the transient analysis of the equivalent circuit of the current transformer using the core model previously described in [10]. The developed routine is fully stable and used to simulate the transient response of the current transformer to asymmetrical fault currents. The capacitive voltage transformer have been modelled by using an equivalent circuit of the single phase CVT. The core has been represented including magnetic non-linearity and saturation effects[9]. The line voltages and currents are fed to the CVT and CT subroutines respectively from the primary power system module. Secondary voltages and currents are calculated and stored for the power system protection signalling.

V. Relay Modelling

The relay model is divided into following four sub-models:

1-) Analogue signal conditioner,
2-) Analogue to digital converter,
3-) Relay algorithm including signal conversion,
4-) Relay status processor.

The analogue signal conditioner models the relay's pre-filter, filter and integrator. These models will have digital transfer functions which represent the analogue transfer functions of the physical components. The analogue to digital converter conditions the filtered signals so that they can be applied to the protection algorithm. This will require reducing the sample rate to the relay sample rate, converting floating point samples to integers, and clipping the signal if necessary.
The inputs to the relay algorithm in general will be DC (Plant Status) inputs as well as the conditioned current and/or voltage samples. The DC (Plant Status) inputs will be stored in the protection unit record. The algorithm will output a trip or no trip operation signal.
The relay status processor will control the implementation of the microprocessor time delay.

<u>Controlling Microprocessor and Circuit Breaker Delays</u>
In order to control microprocessor and circuit breaker delays both the relays and the circuit breaker will be given an operating status, and delays will be controlled by the combination of these states. The possible states are as shown in Figure 5. The top chart in Figure 5 is only a representation of the phase A current after a fault.
At relay model sample No.1 the algorithm outputs a no operation signal thus the relay model status stays in "no operation" and the circuit breaker model remains "closed". Since in real time the microprocessor would still be processing data.
Only after a specified duration will the trip decision be taken. After this delay (three power system model samples) the relay model status becomes "o/p trip" and the circuit breaker model status becomes "operating". The circuit breaker model remains in operating mode until the circuit breaker algorithm determines that it should close. The circuit breaker state diagram is shown in Figure 4. This method of controlling these delays allows the inclusion of a delayed auto reclose scheme, since the method works equally well in reverse.

<u>Filter Evaluation</u>

Filter evaluation is required to check that the digital filter is as accurate a model of the physical filter as possible. A program has been developed to determine the frequency response, of recursive and non-recursive digital filters. This program inputs the transfer function of the digital filter and outputs the gain and phase response over a predetermined range of frequencies. However this program only tests the steady state response of the digital filter, a step response test will be performed to determine its transient response.

Conclusions

In this paper, the modelling and analysis of a unit protection of the simple power system network is explained. The modelling strategy of the system is also described. The complete system is examined in two modules named as primary power system module and the protection system module. Primary power system is modelled in three-phase coordinates . The transducers (CT and CVT) are modelled including magnetic non-linearity and hysteresis effects. The flow diagram of the simple power system with four protection units is explained as used in the program package.

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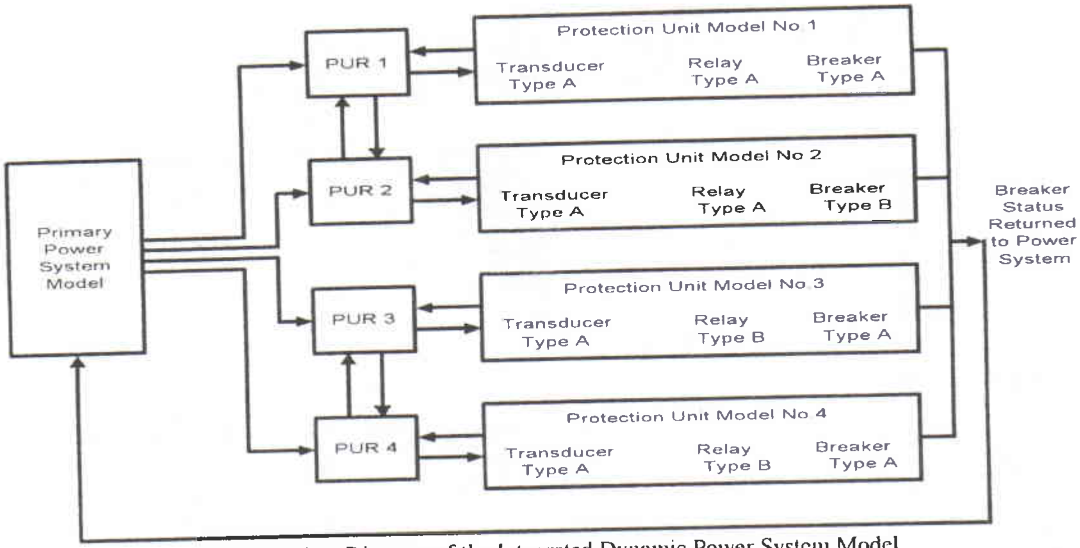

Figure 3: Flow Diagram of the Integrated Dynamic Power System Model

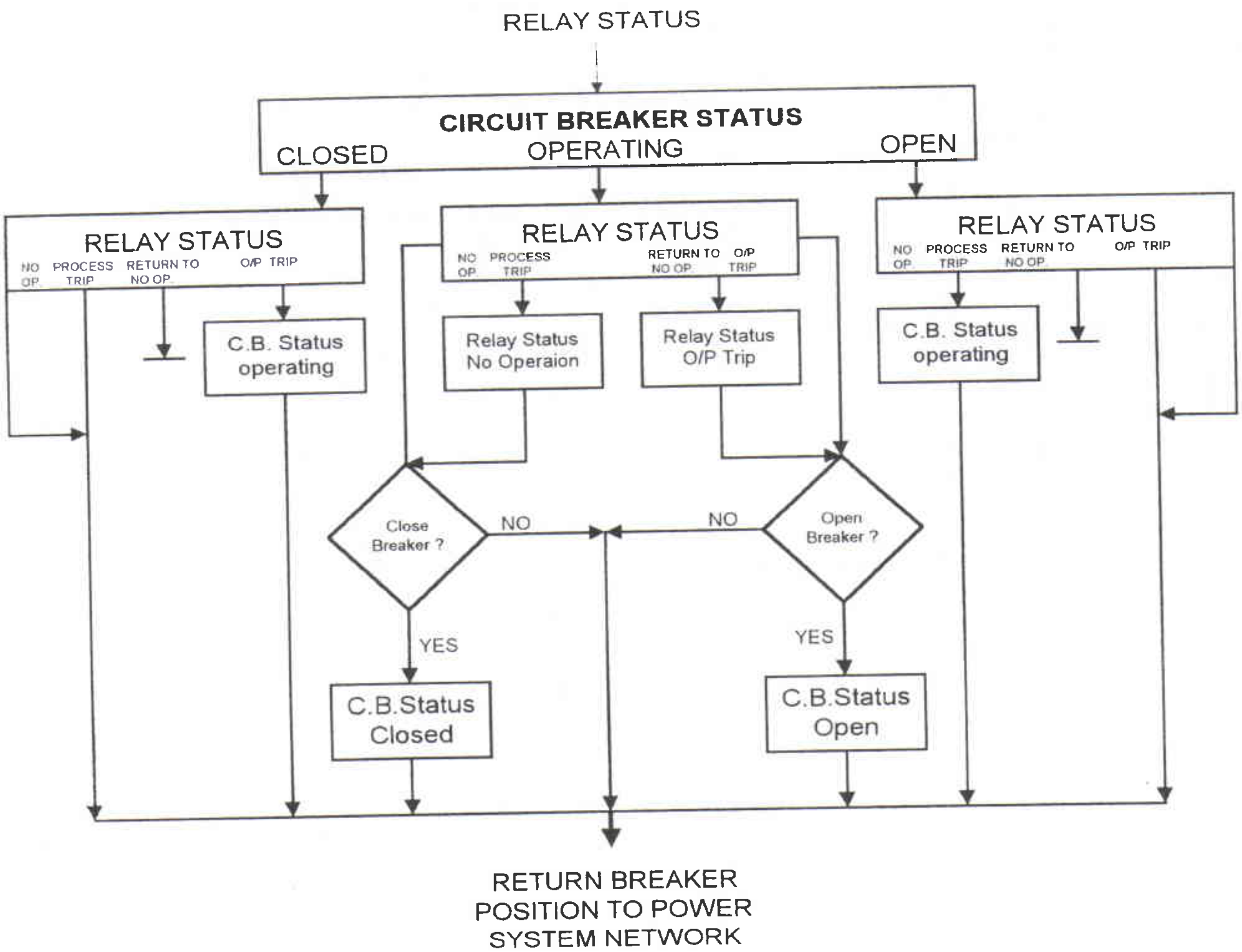

Figure 4: Circuit Breaker State Diagram

RELAY AND CIRCUIT BREAKER STATE TIMING DIAGRAM