A NOVEL APPROACH TO HANDLE THE COLD LOAD PICKUP PROBLEM

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ABSTRACT

Restoration of load after an extended power outage, whether planned or unplanned, raises various practical concerns. Previous studies have shown the cold load condition lasts between 2 to 60 minutes, or longer, depending on the duration of the outage, type of load, and the local weather. The theory presented in this paper is applicable to all microprocessor based overcurrent protective devices used at the distribution level. The example used in the paper is to provide a possible method to handle cold load pickup problems at line reclosers installed on the distribution system.

The new approach is to control the pickup of the phase element of the recloser as a function of time. The pickup of the recloser starts at a preset value after an extended outage and slowly decreases and returns to the normal pickup in a predetermined manner. The relationship of the pickup level and time could be determined by considering the maximum cold load current and its gradual decay with time.

Keywords: Cold load pickup, step-by-step restoration, protective relays, pickup of relays and reclosers, time overcurrent characteristic (TOC) curves, power circuit breaker (PCB).

I. INTRODUCTION

Under normal operating conditions the actual load current on a distribution feeder is considerably less than the total connected load of the feeder, meaning not all of the load operates simultaneously. When a circuit is reclosed automatically after a temporary fault, the inrush current will, generally, not exceed the pickup of the protective devices and the feeder load current will return to normal in a very short time. On the other hand, if the same feeder is exposed to an extended outage, either planned or unplanned, the connected load to the system, i.e., water heaters, electric furnaces, refrigeration, pump motors, air conditioners, etc., will lose its diversity. As a result, more of the connected load will start drawing current from the utility system at the time of energization. This higher load current is called the cold load current and is a combination of three types of current: the magnetizing current of the distribution transformers which lasts for a few cycles, the inrush current of motors which lasts for many seconds, and the current drawn by the loads which takes many minutes to come back to the normal value [1,2,3,12]. The magnitude and duration of the cold load current depends on many factors such as, type of load and set points of the appliances connected to the system, local weather conditions, duration of the outage, thermal characteristics of the buildings, and the habits of the customers. Problems associated with this type of phenomenon are generally referred to as cold load pickup (CLPU) problems. Fig. 1, shows an example of cold load current magnitude versus time.

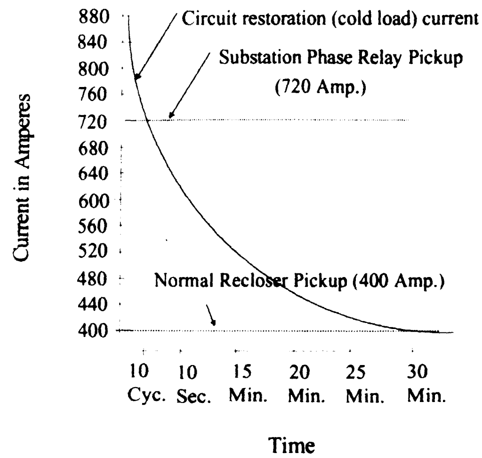

Fig. 1. Circuit restoration current after a prolonged outage

System protection engineers generally design the protection scheme in such a way that the station relay or other downstream protective device isolates a faulted section in the shortest period of time. The protection schemes are not designed to protect the equipment from overloads of the circuits. To provide adequate protection for end of line faults, it is desirable to have a low pickup for the protective devices. The lower the pickup, the greater the chance to operate on CLPU. At the same time, the main (recloser) and backup (PCB relays) protective devices are required to maintain a coordination margin (0.2 - 0.5 seconds) for various types of faults, as per standard utility practices.

Previous research on cold load currents has attempted to understand and model the circuit restoration current with the passage of time [2 to 9]. However no technique has been developed to handle cold load restoration problems in an efficient way, except for the revision of operating procedures. The primary purpose of this paper is to provide an alternative method to handle CLPU problems on a distribution system. Although a microprocessor based recloser controller is referred to, the theory presented here is also applicable to other microprocessor based overcurrent protective devices used at the distribution level.

A recent IEEE survey [10] indicates that 75% of the 102 participating utilities had CLPU problems on their distribution system. Time overcurrent tripping as a result of CLPU was initiated by phase relays 60% of the time, ground relays 10% of the time and both phase & ground relays 30% of the time. 95% of the cold load problems occurred after an outage of at least

15 minutes. Fig. 2, shows the cold load current duration versus the percentage of outages as reported in the survey.

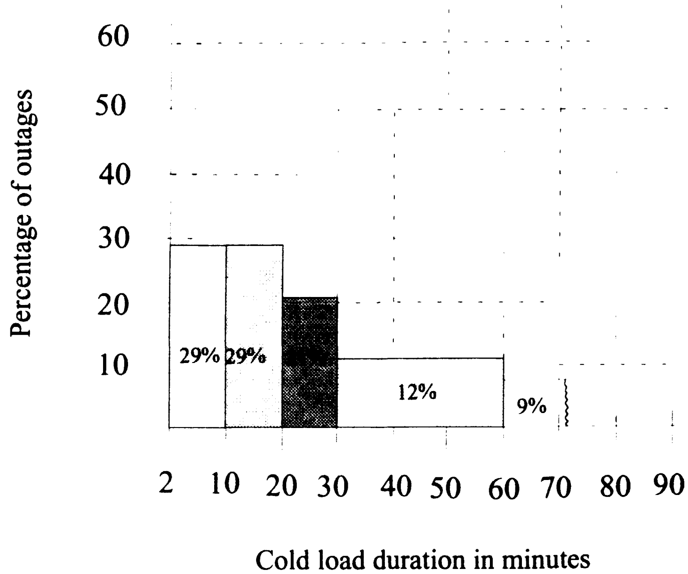

Fig. 2. Cold load duration versus percentage outages

II. SYSTEM DESCRIPTION

The following describes the Puget Sound Power & Light Co. (Puget) distribution system which will be used as a reference in this paper.

Voltage Level:
13.09 kV line to line, Y grounded

Substation PCB relays:
Maximum Design Load Current: 600 Amps.
Phase Element Pickup: 720 Amps.
Ground Element Pickup: 360 Amps.

Recloser controller (when used):
Maximum Normal Load Current: 200 Amps.
Phase Element Pickup: 400 Amps.
Ground Element Pickup: 340 Amps.

As shown in Fig. 3, a typical distribution substation at Puget has a 15/20/25 MVA Delta-Y grounded transformer with four feeders connected to it.

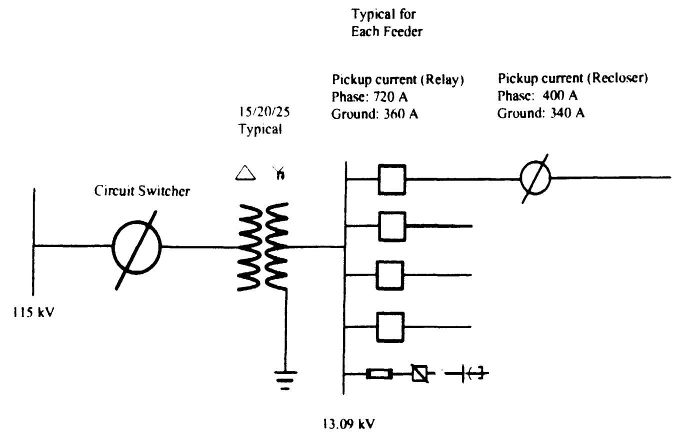

Fig. 3 Distribution Station/Feeder Protection

In Fig. 4, the operating characteristics for the phase elements of a substation feeder breaker relay and a line recloser are shown. Curve #1 is the substation power circuit breaker (PCB) relay having a pickup of 720 Amperes with a time dial of 2.7. Curve #2 is the line recloser phase element having a pickup of 400 Amperes.

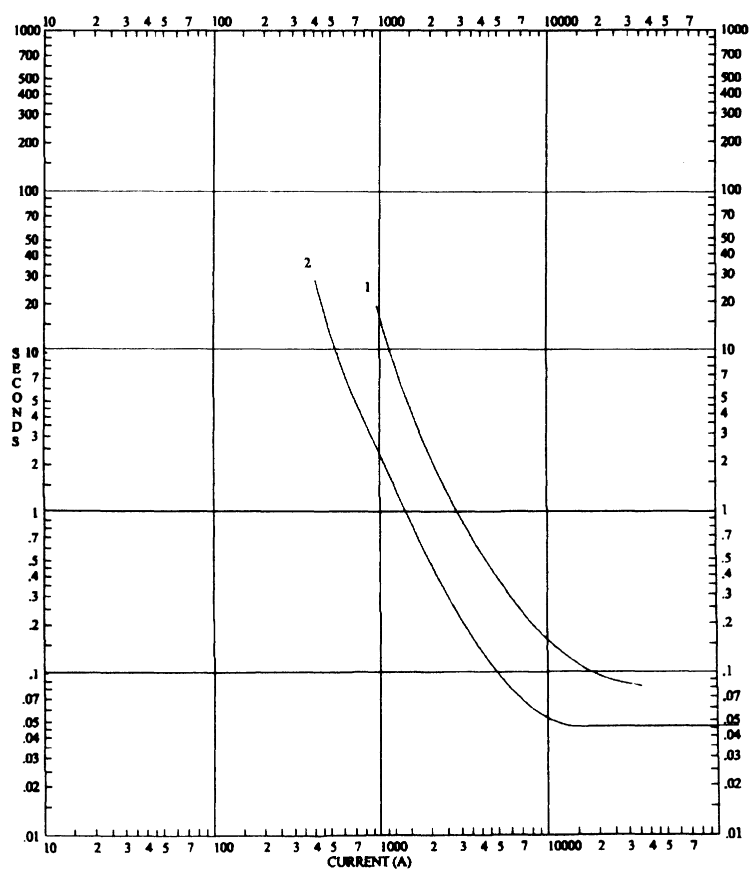

FIG. 4. TOC curves for phase elements of PCB relays (curve#1) and line recloser (curve #2).

III. DISCUSSION

All microprocessor based recloser controllers (recloser controls) that are available in the market have two sets of operating characteristic curves, "fast" and "slow or delay". Examples of fast and slow TOC curves are shown in Fig. 5. Holding the Close Switch in the closed position temporarily transfers the protection of the recloser from the fast coordination curve to the slow curve. The slow curve is activated for the time interval while the Close Switch is held closed, and the protection is transferred back to the normal (fast) curve as soon as the switch is released. However, Puget uses only slow curves for the phase and ground protection on the line reclosers. Therefore, holding the Close Switch in a closed position does not alter the protection of the circuit for the reclosers.

If a slow phase curve is used in combination with a fast phase curve, then the Close Switch has to be held in the close position long enough to allow the cold load current to subside. This is only applicable when the cold load current duration is less than the operating time of the slow curve. This raises two questions; 1) What is the cold load current initial peak value, and 2) What is the cold load current duration? If it is assumed that the initial cold load peak duration is above the pickup and below the operating time of the slow curve, then the operator has to hold the Close Switch in the close position until the cold load current has subsided. In most cases, if the cold load current is above the pickup, it will persist longer than the operating time of the slow curve. Therefore, holding the Close Switch in the close position will not provide any real benefit.

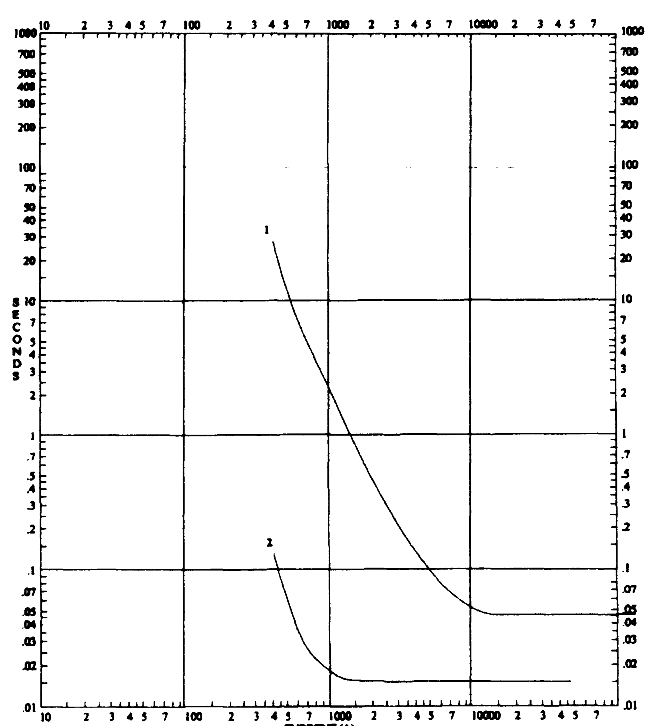

Fig. 5. Comparison of slow and fast curves. Curve#1 Recloser phase element slow curve with 400 Amp pickup, Curve#2 Recloser phase element fast curve with 400 Amp pickup.

IV. FINDINGS

The standard practice at Puget, like many other utilities, is to pick up the load in sections whenever there is a CLPU problem. However, this practice is not strictly followed. On some occasions, personnel have bypassed the recloser instead of picking up the load in sections, thus tripping the entire feeder due to cold load current or phase imbalance.

During a recent telephone survey, it was found that most of Puget's neighboring utilities use both slow and fast curves with distribution line reclosers. The recloser Close Switch is held closed momentarily (for 4-5 seconds) to allow the magnetizing current of distribution transformers to subside. If the recloser operates, load restoration is made in sections. These utilities also provide annual training, for the operating personnel, on the energization of feeders experiencing cold load pickup problems.

For many years, Operation & Protection engineers have tried several techniques to handle CLPU without success. The techniques used previously include:

- Disabling the feeder relay
- Raising the pickup of phase and/or ground elements of the recloser controller and/or substation breaker relay
- Bypassing the recloser for the CLPU duration
- Picking up the load in sections

Obviously, the first method is not a wise choice and would require the backup protection to operate for any fault on the feeder. The backup protection, which is the transformer fuses or the circuit switcher relay, would be slower in clearing the faults beyond its normal zone of protection. In the second method, the higher pickup settings result in desensitizing the protection for the normal operation of the feeder. However, these settings are satisfactory for the CLPU cases. The third method defeats the purpose of installing the recloser, and requires the backup protection (substation PCB relays) to operate for faults beyond the recloser. This results in slow clearing times for line end faults. The fourth method is widely used, but requires the operator to wait for the load current to drop below the recloser pickup and successively load the circuit in steps. This step-by-step load restoration technique is expensive due to the man hours required. It is also undesirable from a customer service point of view because it extends the outage time.

V. NEW APPROACH

The proposed new approach does not use any of the above methods. This approach takes advantage of microprocessor controls, not commonly available previously.

The new approach is to control the pickup of the phase element of the protective device as a function of time. Using a recloser controller as an example, the pickup of the recloser would start at a higher than normal value, after an extended outage, then slowly decrease and return to its normal pickup in a predetermined manner. As an example, the recloser phase element pickup starts at 700 Amperes and stays there for 10 seconds, then drops to 600 Amperes for approximately 15 minutes, then drops to 500 Amperes for 30 minutes. After 30 minutes, the pickup would drop to its normal 400 Amperes. This is shown in Fig. 6, as curves 1 to 4, also, curve 5 shows the operating characteristics of the phase relay at the substation breaker. The relationship of the pickup level and time could be determined by considering the maximum cold load current and its gradual decay with time.

In this example, the 700 Amperes pickup is only for 10 seconds to allow for magnetization inrush and motor inrush currents. If at the same time there is a fault on the feeder involving ground, the ground element will trip the recloser, since the ground protection is not modified. The ground element will still pickup at 340 Amperes at the recloser and 360 Amperes at the substation breaker relays. The phase element of the recloser control has been modified but still maintains the minimum coordination interval.

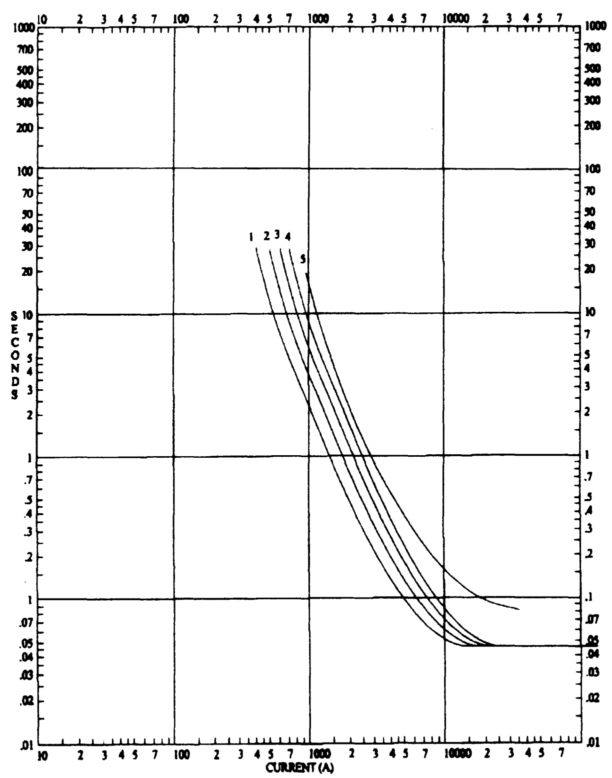

Fig. 6. TOC curves for recloser phase elements (1 - 4) and relay phase element (curve 5)

The curve controlling the pickup of the phase element could be a step function or a continuous decaying curve, as the user desires. A step function was assumed in the example and is illustrated in Fig. 7. The curve shown in Fig. 7, is called the CLPU curve. The maximum value for the CLPU curve can be chosen from previous experience on that feeder. The final value of the curve shall be the normal pickup of the recloser.

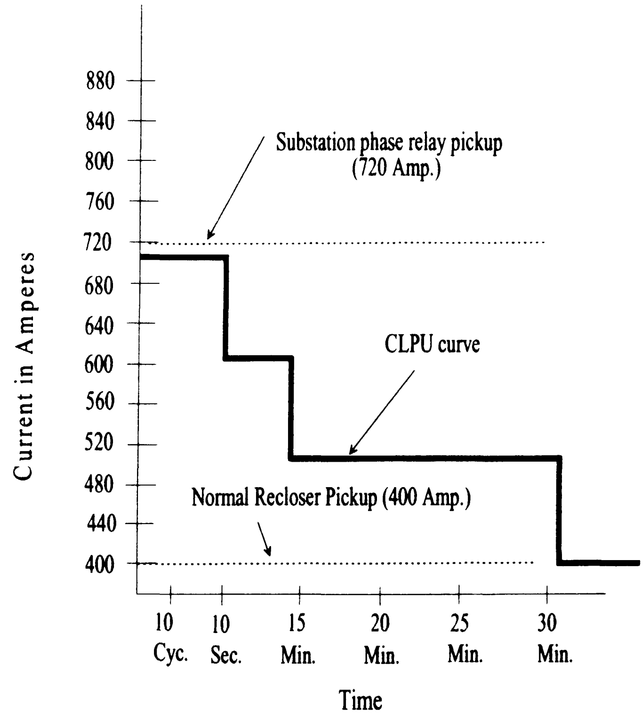

Fig. 7. CLPU example curve

In Fig. 8, the curves from Fig. 1, and from Fig. 7 are shown together. Fig. 8, shows that if the CLPU curve is above the circuit restoration curve, then the protection device will not trip on cold load current.

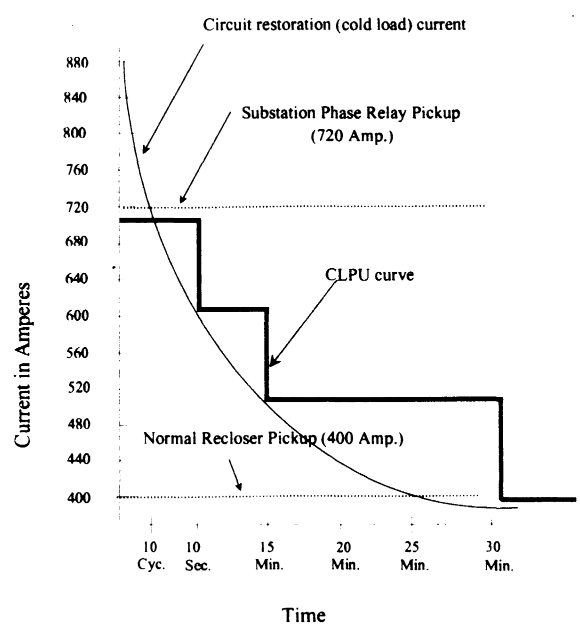

Fig. 8. Circuit restoration current
VS
CLPU example curve

VI. ASSUMPTIONS

1. The maximum pickup of the recloser for CLPU cannot be higher than the pickup of the substation power circuit breaker relays.

2. CLPU curve will be used only when:
   - Feeder has balanced load.
   - Feeder is not loaded beyond its design limits.

3. The CLPU curves shall be used only to control the phase pickup of the recloser or feeder breaker relay.

VII. CONCLUSION

Different techniques commonly used to deal with CLPU problems were discussed and key disadvantages of each technique have been presented. An efficient, simple and economical way has been suggested to handle cold load pick up problems on distribution feeders.

The addition of the CLPU curve in the recloser control and in the relay is recommended. A methodology to allow the user to define and initiate the CLPU curve will need to be devised. As an example, the CLPU curve can be activated by contact closure or a front panel switch. Some utilities may want to program the recloser controller or the protective relay in a way that the CLPU curve is always activated whenever the device is closed manually. The CLPU curve could be an inverse time characteristic curve with the same pattern as the cold load current or could be a step function. The CLPU curve should control the pickup of the phase element of the device. The pickup of the phase element of the device would be forced to start at the value set by the CLPU curve and decay to its normal pickup as time passes.

VIII. FUTURE DIRECTION

The technique proposed in this paper could also be utilized when adaptive relaying becomes available [11]. An artificial neural network could also be used to make a decision for the pickup and the time duration of the cold load current curve.

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X. ACKNOWLEDGMENT

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XI. BIOGRAPHY

<u>Ozair Mirza</u> was born in Karachi, Pakistan in July 1956. He received his B.S. in Physics, Mathematics and Statistics from University of Karachi, Pakistan in 1975. He received his B.S. in Electrical Engineering from NED University of Engineering & Technology Karachi, Pakistan in December 1981. After graduation, he taught at Pakistan Naval Engineering College for one term and then worked for a local construction company as a site engineer. He worked for Karachi Electric Supply Corporation, Karachi, Pakistan in the "Planning and Design" and "Transmission Lines and Substations Construction" departments from August 1982 to December 1989. In December 1989, he joined the University of Washington as a Research Assistant and completed his MSEE in December 1991. In summer 1990, he worked for Snohomish County PUD#1, Everett, Washington in the substation design department. Since March 1991 he has been working with the System Protection Group (presently on temporary assignment to Technical Field Services) of Puget Sound Power & Light Co., Bellevue, Washington. Mr. Mirza's area of interest includes system protection, database for protection engineers, conservation through voltage reduction, and the application of artificial neural networks to power systems.