Ауылшаруашылық нысандарын электрмен қорғаудың тиімділігін арттыру бойынша ұсыныстар ұсынылады. 0,38 кВ электрмен жабдықтау жүйесінің параметрлерін таңдау ұсынылды, ол авариялық токтардың электромагниттік шығарылымдарының жұмысының шектік деңгейіне (немесе оларға жақын) жетуін қамтамасыз етеді және өрт қауіптілік индикаторларын ескере отырып қорғау жүйесін жобалайды.

The article presents the state, technical characteristics and modes, analysis of low-voltage power supply networks of agricultural enterprises.

The main types of damage are indicated, the analysis of damage in existing networks is carried out, methods of relay protection are presented.

The analysis of protection of rural transformer substations is carried out. Their shortcomings and measures to improve the reliability and efficiency of use are identified.

Recommendations are proposed for increasing the efficiency of electric protection of agricultural facilities. It was recommended to select the parameters of the 0.38 kV power supply system that ensure that the emergency currents reach thresholds (or close to them) of the operation of the ER circuit breakers electromagnetic releases, and design the protection system taking into account fire hazard indicators.

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CALCULATION AND MODELING OF EMERGENCY MODES IN DISTRIBUTION NETWORKS

This article offers an introduction to radial feeder protection, and presents the feeder system to be used in this study. The modeling of the feeder system and its components is described. Two overcurrent protection schemes, based on definite-time and inverse-time overcurrent relays, are developed. Performance, based on coordination and selectivity, is evaluated for both protection schemes.

Simulations are conducted in PSCAD/EMTDC. Bolted faults, comprised of SLG (Single Line – Ground), DLG (Double Line – Ground), LL (Line-to-Line) fault, and 3 fault types, are applied at selected locations. The detection of high impedance faults is also investigated.

Both protection schemes are able to isolate the bolted faults successfully. The inverse-time scheme features faster relay operating times (in primary zone of protection) compared to the definite-time scheme. High impedance faults can be detected on both the line current and zero sequence current, although large non-detection zones are present on the line current.

Keywords: the fault protection scheme, distribution system, radial feeder, zone of protection coordination time interval.

INTRODUCTION

The fault protection scheme of a distribution system has the objective of isolating faults from the system in a timeframe that prevents damage from occurring to components. In the process of removing faults, the smallest necessary section of feeder should be isolated, so that the maximum number of loads continue to be supplied. Relays are utilized to provide the signals instructing circuit breakers to open.

MAIN PART

In a radial feeder, only a single source is present, resulting in current flowing in only one direction. The relays are coordinated in the upstream direction, in which the units farthest from the grid connection are configured to operate first [1, 2].

As shown in the simple radial feeder in Figure 1, faults on the line are cleared by opening the breaker immediately to the left (upstream). Each relay and breaker pair (CB1, CB2, CB3) is responsible for clearing faults in an associated zone of protection (Zone 1, Zone 2, Zone 3 respectively), as well as acting as backup for any units downstream. The relays are timecoordinated, so that in the event of a fault, the downstream units are configured to trigger a period of time faster than the upstream units. This coordination time interval (CTI) allows time for the fault to be isolated before backup units are tripped [1, 2].

The protection scheme may feature definite-time or inverse-time relays, as shown in Figure 1. Inverse-time protection offers shorter tripping times, albeit at a greater equipment cost. The relay furthest downstream is typically a definite-time unit, since it is not required to coordinate with any relays further downstream.

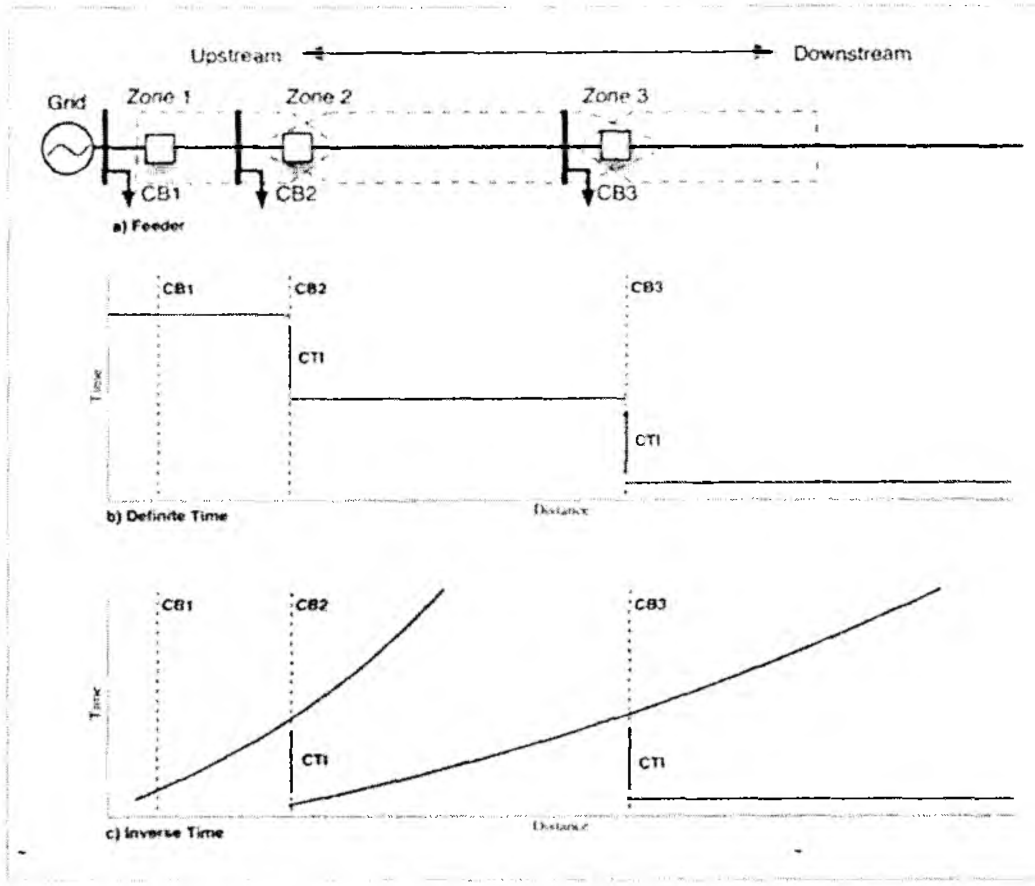


Figure 1 – a) Feeder zones of protection, b) Definite-time protection scheme, c) Inverse-time protection scheme [2]

The distribution feeder utilized in the study is a 10–35 kV three-phase system based on a rural feeder [3]. Recently, in places with a large number of consumers of electric energy, cases of supply voltage of 27 kV are known.

The layout is radial, with a series of three-phase loads and two subfeeder branches that feature single-phase laterals. The utility is represented as a voltage source, with equivalent positive-sequence and zero-sequence impedance labeled. The feeder is a four-wire system, with a single neutral grounding point at the grid connection. A regulator is situated 12-km down the line to adjust the voltage profile so that it fits within ±0.06 pu voltage variation requirements. The point-of-common-coupling (PCC) is located at CB2 and marks the boundary for the portion of feeder which can operate in islanded mode. Single-phase laterals exist off the main trunk, but not on the low side of the lateral transformers. The layout of the study feeder is shown in Figure 2, with segment lengths stated in meters, and cable types labeled.

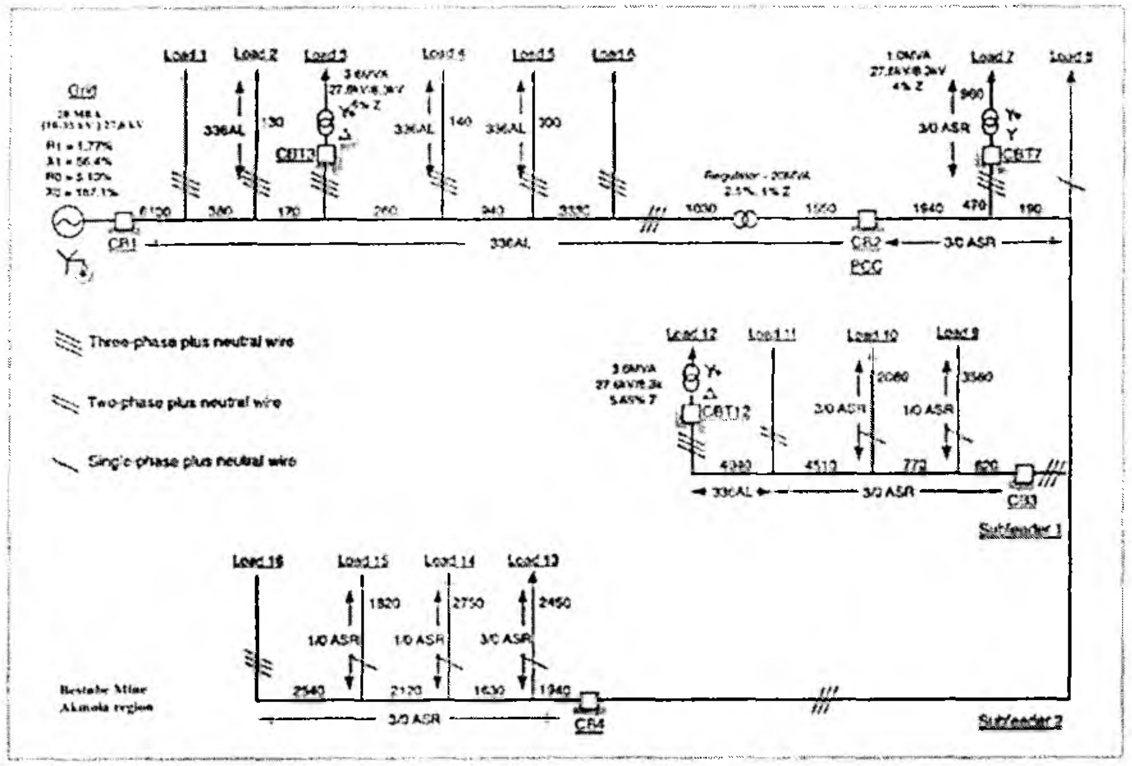


Figure – 2 Study system layou

The cable parameters are given in Table 2–1. Load parameters are given in Appendix A.

Table 2–1 – Cable parameters [3]

	Positive-Sequence			Zero-Sequence		
Cable Type	R_1, ohms/km	X_1, ohms/km	B_1, uS/km	R_0, ohms/km	X_0, ohms/km	B_0, uS/km
336 AL	0.1696	0.3809	4.33	0.4689	1.2808	1.90
3/0 ASR	0.3480	0.4680	3.76	0.7020	1.3220	0.00
1/0 ASR	0.5523	0.4852	3.60	0.9644	1.4610	1.92

The three-phase lines are represented using three-phase, four-wire PI sections [4]. The various loads, specified in real and reactive power, are modeled as series resistors and inductors, whose values are calculated using the rated line-to-ground voltage of 16 kV (or 4.8 kV line-to-ground for loads on the low-voltage side of a transformer). Details regarding load parameters are given in Appendix A.

The faults under investigation include both bolted and high impedance faults, and cover SLG, DLG, LL, and 3 fault types. Bolted faults are represented by a zero-impedance connection to ground or between phases.

A model was developed for simulating high impedance SLG faults, featuring two distinctive characteristics – a gradual buildup to the steady-state fault current level and non-linearity – as observed in KEPCO's experimentally obtained waveforms [5]. A high impedance SLG fault model consisting of two time-varying resistors is outlined in [5]. One resistor is utilized to simulate the non-linearity, while the second resistance decreases with time to obtain the current buildup characteristic.

An alternate method of modeling the non-linearity is presented by Etemadi in [6], utilizing a diode-resistor-voltage source pair. As this study's goal is to investigate current-based protection, the simpler model in [6] is used in place of one of the time-varying resistors specified in [5].

The KEPCO model [5] and Etemadi's model [6] are combined for use in this study, and is shown in Figure 3. Resistor R1 varies with time and is responsible for simulating the buildup of the current waveform. Analysis of the build-up current waveform in [5] shows that the resistance behaves according to (1):

$$R_1(t) = \frac{1780}{(1+75t)} - 44t. \qquad (1)$$

where:

$R_1(t)$: time-varying resistance of R_1,

t: time after fault occurrence.

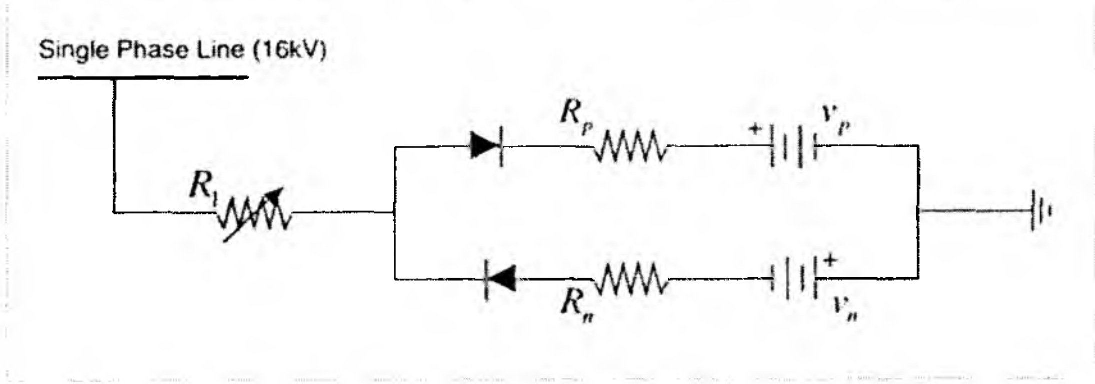


Figure 3 – Combined high impedance fault model

The inception voltages vn and vp are both set to 7000 V, so as to obtain the non-linear waveform observed in [5]. The resistor pair R_n and R_p is varied to obtain the required fault current. The model characteristics are compared to the measured waveforms in [5] in Figure 4 and Figure 5.

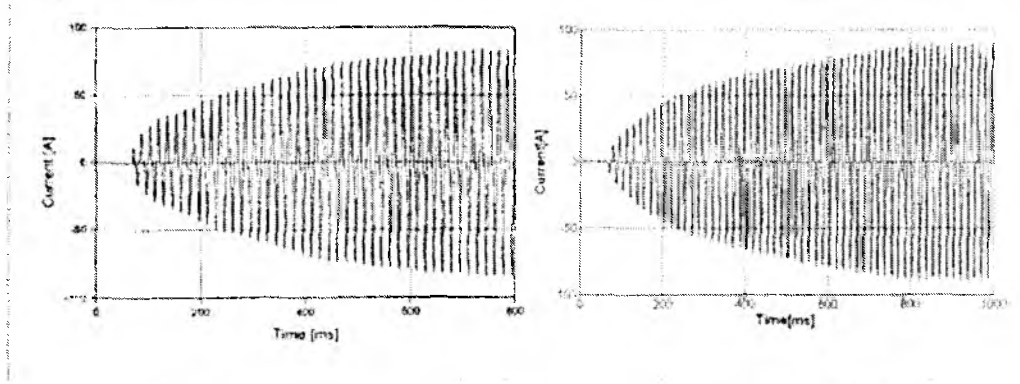


Figure 4 – a) Measurement buildup waveform [13],
b) Modeled buildup waveform

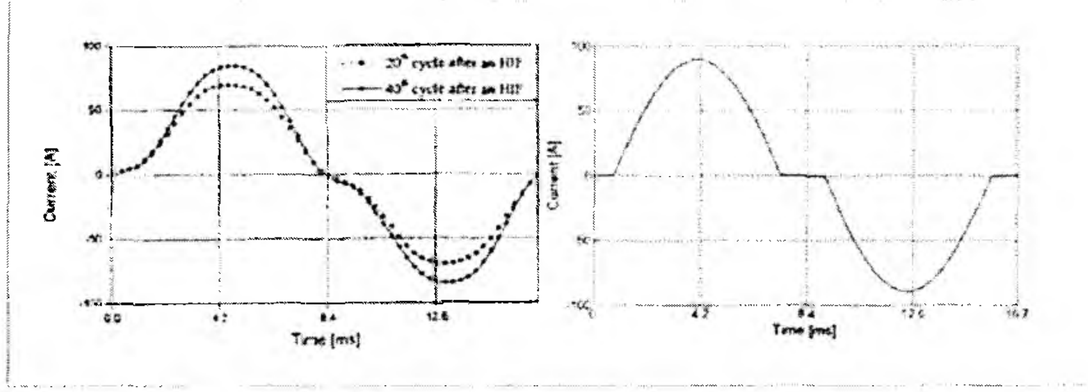


Figure 5 – a) Measurement non-linearity waveform [5],
b) Modeled non-linearity waveform

Typical RMS currents for high impedance SLG fault conditions are given for a 12.5 kV feeder in [7]. Assuming a constant average impedance, the fault currents are scaled up to the 27.6 kV of the study feeder system. Based on the currents scaled from [7], the settings for resistor pair R_n and R_p in the high impedance fault model are calculated according to (2):

$$R_p = \frac{v_{line(L-G)} - v_p}{i_{fault}},\ R_n = \frac{v_{line(L-G)} - v_n}{i_{fault}}. \quad (2)$$

where:

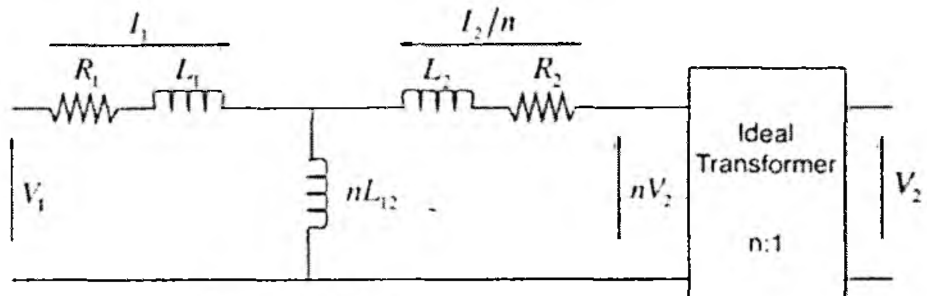
$v_{line(L-G)}$: line-to-ground voltage,
i_{fault}: fault current,
v_p, v_n = 7000V, inception voltage.

The fault conditions, reference RMS current [7], scaled RMS current, and resultant R_n and R_p values are presented in Table 2.

Table 2 – High impedance fault parameters

Fault Condition	RMS Current (A) for 12.5 kV	RMS Current (A) for 27.6 kV	R_p and R_n (Ω)
Wet Sand	15	33.3	270.0
Dry Sod	20	44.4	202.5
Dry Grass	25	55.6	162.0
Wet Sod	40	88.9	101.3
Wet Grass	50	111.1	81.0
Concrete (reinforced)	75	166.7	54.0

The transformers are modeled as a T-equivalent circuit with ideal transformer, as shown in Figure 6.



$$L_1 = L_{11} - nL_{12}$$
$$L_2 = n^2 L_{22} - nL_{12}$$

Figure 2 – Transformer T-equivalent circuit

where:

V_1, V_2: terminal voltages of high-voltage and low-voltage sides
R_1, R_2: resistance of copper
L_{11}, L_{22}: self inductances of high-voltage and low-voltage sides
L_{12}: mutual inductance
n: turns ratio

CONCLUSION

Successful relay operation is achieved when a fault is isolated while disconnecting the smallest necessary portion of feeder. For the radial case, this is realized through the opening of the closest upstream relay. Fault locations inside the circuit breakers are not considered. For faults in each zone of protection, this is defined as:

– For faults in Zone 1 but outside any other zone, CB1 should open.

– For faults in Zone 2 but outside any other zone, CB2 should open, with CB1 as backup.

– For faults in Zone 3 but outside any other zone, CB3 should open, with CB2 and CB1 as successive backups.

REFERENCES

1 **Кислов, А. П., Марковский, В. П., Кайдар, А. Б., Шапкенов, Б. К., Арипова, Н. М.** Анализ эффективности управления перетоками активной мощности при возникновении асинхронного хода в электроэнергетической системе. / Вестник ПГУ. – № 1. – 2015. – С. 146–160.

2 **Кайдар, А. Б., Шапкенов, Б. К., Кислов, А. П., Жанат, Ж., Айтжанов, С. Е., Жакып, К. Б., Файзулла, Д. Ф., Джансаринов, К. Е., Оспанова, Ж. М.** Тұрақты токтың салғылары мен желісінің колдану проблемалары мен тиімдіжағы. // Вестник ПГУ. Энергетическая серия. – № 4. – 2015. – С. 65–69. ISSN 1811-1858.

3 **Kopyrin, V. S., Kaidar, A. B., Ivanova E. V., Novozhilov, A. N., Kislov, A. P., Markovsky, V. P., Shapkenov, B. K.** Diagnostics the fault types and fault locations in a cascaded mlid from its output voltage waveform. // Вестник ПГУ. – № 4. – 2014. – С. 49–59.

4 Векторное сопряжение разнохарактерных источников энергии Марковский В. П., Кайдар А. Б., Кайдар М. Б., Шапкенов Б. К., Кислов А. П., Кулумбенов С. Ж. // Вестник ПГУ, ISSN: 1811-1858. Энергетическая серия – № 3. – 2018. – С. 122–132.

5 **Шапкенов, Б. К., Кайдар, А. Б., Кайдар, М. Б.** Оптимизация параметров и режимов работы городских электрических сетей: монография / Б. К. Шапкенов, А. Б. Кайдар, М. Б. Кайдар. – Алматы : Эверо, 2016. – 176 с. – ISBN 978-601-310-762-2.

6 Повышение эффективности электроснабжения городских электрических сетей : Монография / Б. К. Шапкенов, А. Б. Кайдар, А. П. Кислов, В. П. Марковский, М. Б. Кайдар. – Павлодар : Кереку, 2016. – 153 с. – ISBN 978-601-238-674-5.

7 **Shapkenov, B. K., Kaidar, A. B., Kaidar, M. B., Markovskiy, V. P., Kislov, A. P.** The operational features and detailed control schemes of AC sub-microgrid, dc sub-microgrid and hybrid ac/dc microgrid, c.128-138. «XIX Сәтбаев оқулары» жас ғалымдар, магистранттар, студенттер мен мектеп оқушыларының : халықар. ғыл. конф. мат-дары Академик Қ. И. Сәтбаевтың 120 жылдығына арналған. – Павлодар : С. Торайғыров атындағы ПМУ, 2019. ISBN 978-601-238-907-4. Т. 21 «Жас ғалымдар». – 2019. – 420 б. ISBN 978-601-238-930-2.

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Расчет и моделирование аварийных режимов в распределительных сетях

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Бұл мақалада радиалды фидерді қорғауға арналған кіріспе ұсынылған және осы зерттеуде қолданылатын фидер жүйесі енгізілген. Беру жүйесі мен оның компоненттерін модельдеу сипатталған. Уақыт пен кері уақыттың шамадан тыс релесі негізінде екі қорғаныс схемасы жасалды. Үйлестіру мен таңдауға негізделген өнімділік екі қорғаныс схемасы үшін де бағаланады.

Модельдеу PSCAD/EMTDC-де жүргізіледі. Таңдалған орындарда SLG (бір жол – жер), DLG (қос сызық – жер), LL (түзу сызық) және үш типтен тұратын ақаулар қолданылады. Сондай-ақ, жоғары кедергілік ақауды анықтау да зерттелуде.

Екі қорғаныс схемасы болттардағы ақауларды сәтті табуға қабілетті. Кері уақыт тізбегінде белгілі бір уақыт тізбегіне қарағанда жылдам релелік жауап беру уақыты бар (негізгі қорғаныс аймағында). Жоғары кедергісі бар ақаулар сызықтық токпен де,