Eng. &Tech.Journal, Vol.34,Part (A), No.6,2016

Protection Coordination with Distributed Generation in Electrical System of Iraqi Distribution Grid

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Received on:19/11/2015 & Accepted on:9/3/2016

ABSTRACT
The nature characteristic in conventional distribution networks is radial by single source supplying a downstream network. The interest about the environmental impacts and development in technologies have led to increase distributed generation (DG) interconnected in distribution networks. Protective device coordination will be affected by adding DGs to the existing network through participating to the change in direction of power flow and fault current values and direction which cause loss in settings and mis-coordination for protective devices, especially over current relays.

The effect of DG on coordination depend upon number, location and size of DG, so in this work, the Particle Swarm Optimization (PSO) technicality utilization to locate optimal location and sizeof DG to obtain minimum active power losses.The Time Current Characteristic (TCC) curves represented which depended on the over current protection relays parameters to find settings and limited any loss in it, in order to reset these relays to obtained the proper operation without intersections in time of operation and satisfy optimal coordination between primary and pack up over current protection relays.

In this work two soft wares are used, the first is Matlab R2014a for implementation of the PSO algorithm while the second software is CYMDist program for load flow analysis, short circuit current calculation and protection coordination device analysis. To verify the developed algorithm parts from Iraqi distribution network (Baghdad Al-Rusafa 33KV distribution networks). So, used two DG units with total capacity 50MW distributed in 33kV of South Al-Rusafa distribution network which represented about 9.4% from the total load of this network 533.5MW, the total active power losses reduced from 11.597MW to 6.658MW with losses reduction 6.96MW about 43% from total losses.

Keywords: Distributed Generation (DG), Particle Swarm Optimization (PSO), Short Circuit Level, Protection Coordination, and Time Current Characteristic (TCC).

INTRODUCTION
On the power system, the increasing demand has raised a difficult assignment to electrical power engineers in preserving a reliable power system. With high loads network, when the system losses and voltage drop increase in distribution system, the environmental variation in design and operation of power systems has required the necessity to activate power distribution network by penetration of an emerging technology in this new period and it provides clean electric power by distributed generation (DG), which is also known in many terms, “Dispersed generation”, “Embedded generation” and “Decentralized generation” [1].

Distributed generation refers any electricity generating technology units located in the effective point of the electric distribution system near to the load center, in order to avoid the extend in

https://doi.org/10.30684/etj.34.6A.12
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the distribution network to cover the increment load and future development for consumers demand or reduce the necessary of energy transfers [2]. The optimal selecting size and location of DGs in electrical distribution system is a complicated problem for optimization and if this problem contain the multiple objective function, this problem become more complex, where optimization is a mathematical tool which can be used to locate and size the DG units in the system, so as to utilize these units optimally within certain limits and constraints [3].
One of the standard protections of distribution substation which detects fault circumstances on feeders and commences a trip signal to separate the faulted equipment is the feeder protection. The radial configuration has been completely used to facilitate the schemes of protective relaying in the traditional feeder protection in distribution systems, especially in coordination between downstream and upstream protective devices of resulting simple relaying. With the DGs existence new sources of fault currents comes from DGs, and the advantages of protection design obtained from radial currents flows are lost, sothe protection coordination between upstream and downstream faced a big challenge[4].
Installation a DG into the distribution system makes a variation in the level of a system fault current and cause many of problems in the protection of distribution system, like protection blinding, short-circuit levels increase, false tripping in the protective devices and mal-coordination between relays**.**To ensure selectivity, it is necessary to set a proper coordination between relays and other protective equipment. Nevertheless, this coordination may be severely obstructed if a DG is connected to a distribution network [5].

The Difficulties and Challenges with DG

i. ***Power loss*: Depending** on the DG location, the losses may increase or decrease, the DG capacity and the proportional size of the load amount, the network topology and other factors.DG unit's location is an important criterion that needs to be analyzed to achieve best system reliability with losses reduction [6].
ii. ***Power quality* :**The quality of power are generally considered of the fluctuations of transient voltage and the mains voltage harmonic distortion.The impact of increasing fault level of the network during adding distributed generationusually leads to the improvement of the power quality, [7].Important power quality problem is a flicker. It refers to rapid voltage changes that can cause significant variations in lighting and electronics to interrupt operations. To reducing flicker of the voltage during decrease the power conditioning system output impedance in standalone mode [6].
iii. ***Reliability*: The** DG units can improve system reliability by ensuring the continuity of power supply. In case of power failure occurring on the upstream main network, the disconnecting a part of the system (containing DG) from the main network can be performed by means of the islanding procedure. In this way, the DG units continuously provide the power to customers of the islanding system. [8].
iv. ***Voltage Regulation: DG*** connection can lead to changes in the feeder's voltage profile by changing the active and reactive power flow magnitude and direction. Also for short-term abnormal voltage can occur when DG is switched off and on. The obtained fluctuation result can have the disturbance impact on the distribution system. However, voltage regulation can be effect positively or negatively when DG penetrated to the distribution system depending on its characteristics and location [9].
v. ***Short Circuit Level*: The** short circuit levels of the distribution system affected by the existence DG in this network. It establish high fault currents with respect to the normal case when the network operate without DG.. The levels of short circuit can be changed enough in the case of a few large units, or many small units, to cause mal coordination between the protection devices such as relays or fuses [10].When a fault occurs, at fault point the fault current is fed from both theutility power system and distributed

generation. The fault cannot be separated, and so continue If the total fault current exceeds the capacity of the power supply circuit breaker [11].

vi. ***Protection coordination*: The** purpose of protection is to isolate the faulty equipment as quickly as possible, with a minimum of disruption to the supply of electricity, and minimal impact system stability. The protection can be considered as a control system as well. It monitors the operation components of the power system such as lines, transformers and generators, and takes action if the component is in a potentially dangerous state, This action is normally opening a circuit breaker, which eliminates completely the supply from the component.[12].

Benefits of DG

The considerable advantages of the installation of DG into electric power networks are as follows [13]:

a) Loss reduction in transmission and distribution lines, which minimizes costs related to loss.
b) Improved reliabilityof the utilitysystem as back-up or stand by power to customers.
c) Power quality improvementand voltage supportoffers customers a choice in meeting their power needs.
d) Release Transmission and distribution lines capacity and reduces or Postponement the needs of new infrastructure.
e) Loweringcoststhrough avoidinglong distanceof the high voltagetransmission lines.
f) Where renewable sources are used with some technologies such as solar or wind DG will be friend of environment.
g) Can reduce the needfor the construction orupgradesoflargeinfrastructurebecause theDGcan bebuilt on the siteof the load.
h) Spinning reserve support during generation outages.

One of the objectives for this paper is to obtain the optimal number, size and locations of DG units to avoid the negative impacts of the ordinary installation of the DG .and then calculate the settings for the relays protective device with and without DG to clarification the coordination with new settings.

Mathematical Formulas

i. ***Power Flow Calculation*: There** are three ordinarily used iterative methods, precisely Gauss-Seidel, Fast Decouple andNewton-Raphsonmethods of analysisto thenonlinearalgebraic equation. These methods are usedto the powerflow problems solution [14]. For considerable power system, the most active and practical method is the Newton-Raphson found. [11].

ii. ***DG optimization using PSO Technique* :**TheDGplanning issuesconsists of twostages,to find the optimallocationbusin the networkand theoptimalDGsize[15].The PSO-based approach to find the optimal size and location of distributed generation unit to reduce active power loss as in the below, Figure (1) represents flow chart of PSO.

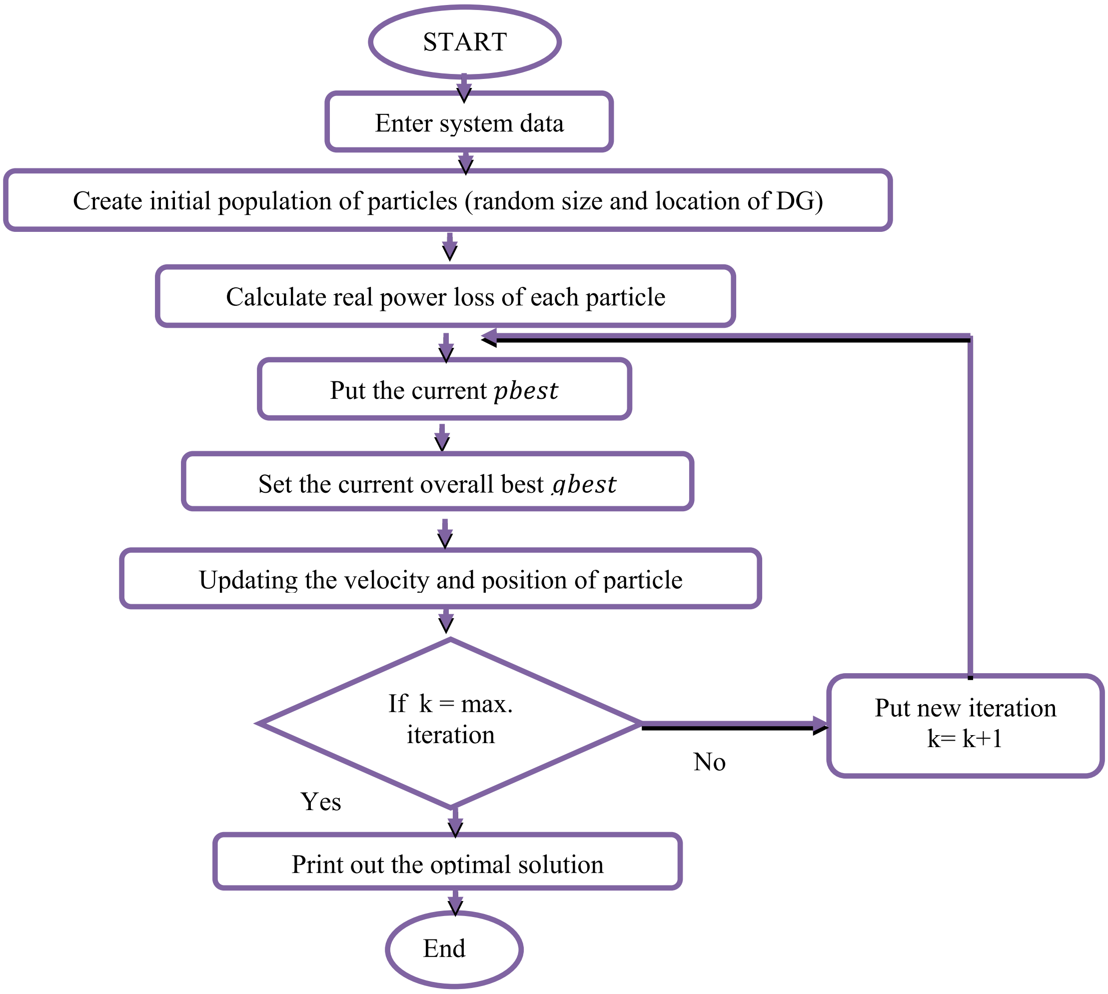


Figure (1): Flow chart of PSO

iii. ***Over Current Protection and Coordination*** [16],[17],[18]**:**Overcurrent relays are usually supplied with time delay element and an instantaneous element in the same unit. An earth-fault unitand three-phase overcurrent unit are the most modernistic microprocessor protection has within the same case. Overcurrent protection relays setting include choosing the time\current characteristic parameters of both instantaneous and the time delay units. The operation achieved in two cases, first one to the phase overcurrent protection relays and the earth fault protection relays secondly.

a) Instantaneous units: In distribution lines to set these units, used one of the two values either between six and ten times the maximum circuit rating or 50 per cent of the maximum short circuit current at the point connection of the CT supplying the relay.

$$Setting\ of\ instantaneous\ element = \frac{0.5\ Isc}{CTR} \quad (1)$$

b) IDMT unit: Inverse definite minimum time protection relays can be modify through choosing two parameters, the time multiplier setting or time dial, and plug setting (tap setting) or the pick-up.

- **pick-up setting:**Expressed to multiples of the pick-up relay and fault currents viewed via use the relay. This value is ordinarily represented the Plug Setting Multiplier (PSM), it is recognize as the plug setting or the ratio of fault current in secondary amps to pickup of the relay. A pick-up setting for phase relays is specified toward permitting a margin higher than the nominal current in overload cases, as in the expressions below:

$PSM = \frac{fault\ current}{maximum\ circuit\ primary\ current}$ (2)

$Pick-up\ setting\ = (OLF\ \times\ Inom)\ \div\ CTR$ (3)

Where: PSM = plug setting multiplier, Inom = nominal circuit current rating, CTR = current transformer ratio OLF = the overload factor which depends on the parameter being protected .It's rang between (50% and 200% in 25% steps). For generators, lines and transformers it recommendedordinarily in the range of 1.25 to 1.5.While in case of a possibility under emergency conditions to increment the load on feeders such as in distribution systems, OLF it could be up to the order of 2.

In earth-fault overcurrent relays, under normal operating conditions the setting of pick-up is specified taking into consideration the maximum disturbance that would present in the system. Atypical disturbance permitted between (10% and 80% in 10% steps).

- **Time dial setting:**When the fault current arrives to a magnitude similar to or more than the setting of relay current, before relay operates the time delay adjusted by time dial setting .Also noted by the time multiplier setting (TMS) which its range between (0.05-1 in 0.05 steps). The procedures for calculating (TMS), to find the convenient coordination and protection to the system are explain in steps below:

Step1: Find the wanted operating time (t1) of the remote relay from the supply source through utilizes the minimum TMS and dependence on a fault level. To coordinate with devices installed downstream which it is necessary; this TMS may have to be higher.

Step2: Find the relay operating time related with the next substation breaker towards the source

$t2a = t1 + td$ (4)

Where: **t2a** the back-up relay desired operating time, **t1** is the operating time of the downstream relay,

td is the discrimination (margin) time for breaker - breaker (IDMT to IDMT relays).

$td = 0.25t1 + 0.25$ (5)

Where: Relay Error Factor = 0.25t1.

Downstream breaker interrupting Time = 100 msec.

Relay Overshoot Time = 50 msec.

Safety Margin = 100 msec.

Step3: The time dial setting calculation for back-up relay through the same current of fault as in the previous 1 and 2 , and find t2a so as the pickup value.

$TMS_{\ new} = \frac{\text{Desired operating time}}{\text{Operating time at selected PSM and TMS 1.0}}$ (6)

Step4: Find the actual operating time (t2b) of back-up relay, but now using the fault level and pickup value where this relay is connected.

$t2b = \text{Operating time at selected PSM and TMS 1.0} \times TMS_{\ new}$ (7)

Step5: Go on with the sequence, beginning from the step2.

Procedure explained above for earth and phase units can readily utilize when the operating characteristics of relays are known by mathematical formulae in lieu of log-log paper curves. Define the operating time mathematically by ANSI/IEEE and IEC Standards in the following expression:

$\boldsymbol{t = \frac{k\beta}{(\frac{I}{I_S})^{\alpha} - 1} + L}$ (8) Where: t = operating time of relay in seconds, Is = selected pick-up current, I = secondary fault current level in amps, k = time multiplier setting, or time dial, L = constant.

The parameters $\boldsymbol{\alpha}$ and$\boldsymbol{\beta}$ determine the relay characteristics slope. These constants with L to different standard of the overcurrent relays processed under IEC and ANSI-IEEE Standard with typical characteristics for both types are given in Appendix (B).

Table (1) Electrical distribution network size for part of Baghdad Al-Rusafa 33KV Network									
Items	substations	Substation Total No.	Transformers Total No.	North Net.		Center Net.		South Net.	
				S.S.	T.R	S.S.	T.R	S.S.	T.R
1	132/33/11KV	6	17	--	--	--	--	6	17
2	132/33KV	15	22	7	11	7	8	1	3
3	132/33KV mobile	1	1	--	--	--	--	1	1
4	33/11kv	57	118	18	35	16	34	23	49
5	33/11kv mobile	2	2	--	--	--	--	2	2

Simulation Results and Discussion for case study

The work is dedicated to the simulation results obtained from the different analysis and calculations for part from Baghdad electric distribution network. Mainly the works are divided in to stages as below:

a. Solving the optimization problem of DG by used Particle Swarm Optimization (PSO) methodswhich has been discussed previously through use (MATLAB R2014a). So the optimal number, sizes and locations of DG will be accomplish in this stage.

b. Find short circuit calculations and protection coordination device analysis by CYMEDist program package with and without DG.

i. ***Baghdad Al-Rusafa Distribution Network:*** Part of Baghdad Al-Rusafa distribution network, the region restricted between army channel and Tigris river and the extended from north to the south of the city with its outskirt.Table (1) illustrate the size of choice part from of Baghdad Al-Rusafa distribution network.

ii. ***South of Al-Rusafa33KV Distribution*** **Network:** The total number of feeder in this part of network is (51) feeders with two types transmission lines, underground and overhead with substations and transformers illustratein the bus and line data of the distribution network are given in Appendix(A)and diagrammatically taken from Iraqi MOE. This part show the highest total loads for south of Rusafa distribution network (533.5MW) compares with two others parts (north and center).The PSO algorithm which was used for the optimal size and locations of DG units near the loads in high voltage side at the 33/11KV transformers with objective function of minimum active power losses, the results to these optimizations in each case as shown in Table (2).The power factor is kept constant ($\cos\emptyset = 0.85\ lag$).

Table (2) Optimal Number, Locations and Sizes of DGwith Total Power Losses for South of Baghdad –Al-Rusafa 33KV Network

Case	Numbers DGs	Size MW	Locations (Bus No.)	Losses MW	Losses Reduction %
1	Without DGs	-----	------	١١.٥٩٧	------
2	1	30	61	٨.٣١١	28
3	1	50	59	9.35	19
4	2	30	62	6.927	40.3
		20	61		
5	2	25	61	6.658	43
		25	62		
6	3	15	62	6.910	40.4
		15	60		

		15	61		
7	3	20	68	6.947	40.1
		15	61		
		15	62		

From the results the optimal locations and size appears in case (5) when use two DG with 25MW for each one of them in location 61(Dawaa substation) and 62 (Zaafraniya substation) to obtained the minimum active power losses to this part of network. The first location 61 located at the end of long 33KV feeder which has three distribution transformers 33/11 KV at the same feeder with high total loads and high drop voltage. Also the second location 62 located at high loads distribution transformer 33/11KV with high drop voltage too.Figure (2) compares between these cases and shows the reduction of power losses for all cases.

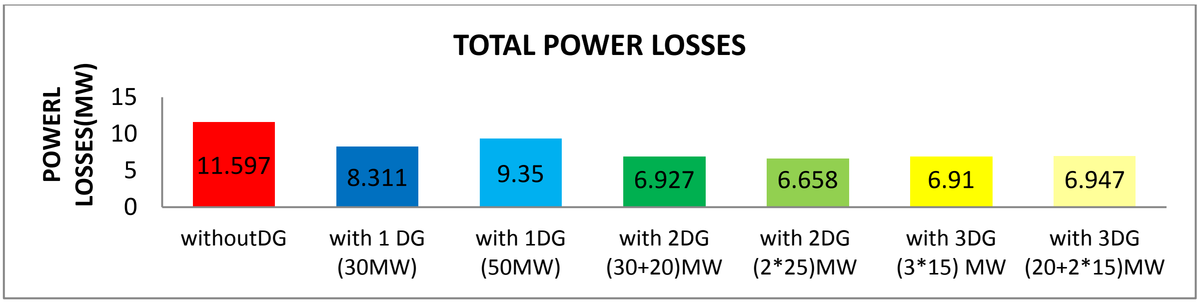
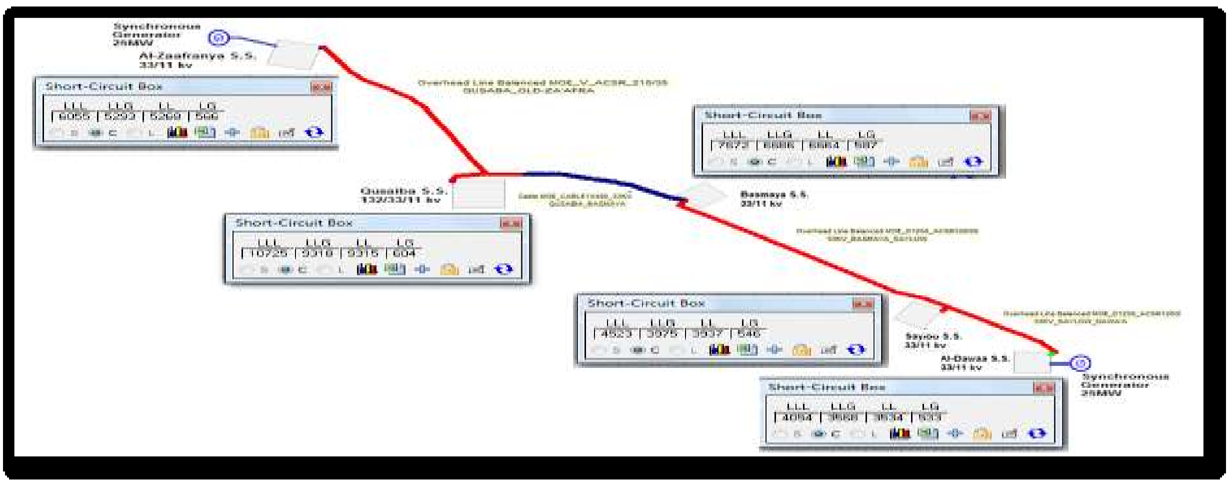


Figure (2) : Total power losses for South of Al-Rusafa 33 Network

Two DG units with total sizes 50 MW (25 MW to each unit) which represent 9.4% with respect to the total load and 5MW losses reduction about 43% from the total active power losses of south distribution network.

iii. Short Circuit Current Calculation forEmbedded Two Distributed Generation(25MW) Near Al-Dawaa and Al-Zaafraniya 33/11KV Substations

In this case, the effect in the short circuit current was determined through embedded two DGs in size of 25MW for each one which represents the optimal number, size and location that PSO limited, one of them near Al-Dawaa substation and the other one near Al-Zaafrainya substation. Figure (3) shows the 33kv feeders and substations and the results of short circuit current for different type of faults after DGs embedded. All results are summarized in Table (3).



Figure(3) 33KV Feeders (Qusaiba_Zaafraniya and Qusaiba_Dawaa)withTwo DGs

Table(3) Short Circuit Currents Magnitude for Embedded two DGs								
Fault Type	QusaibaS.S.Amp.		Dawaa S.S. Amp.		Zaafra S.S. Amp.		25MW DG Dawaa Amp.	25MWDG Zaafra. Amp.
	Without DG	With DG	Without DG	With DG	Without DG	With DG		
L LL	8241	10725	2431	4054	4214	6055	4029	5954
L G	215	604	191	533	202	566	532	565
LL	7137	9315	2105	3534	3650	5268	3513	5181
LLG	7137	9318	2124	3568	3661	5293	3546	5205

iv. Setting and Protection Coordination

Through using protective device coordination analysis in CYMEDist program to represent Time Current Characteristic (TCC) curves by branch device coordination feature, for south of Al-Rusafa distribution network with this simulation steps for relay coordination:

- **a.** The system is simulated without DG to get the fault Currents.
- **b.** The relays are set for the fault currents and coordinated without DG.
- **c.** DG is connected to the system to get the new fault currents.
- **d.** The operating time is checked after DG connection.
- **e.** The relays are coordinated with new fault currents and operating time.
- **f.** The new coordination margin is calculated.
- **g.** Loss of coordination is checked.
- **h.** New settings are selected for the relays to accommodate the DG

Case (1): Without DG

The current network depend on one circuit breaker in 33KV side of Qusaiba substation contain over current relays with specifications in Appendix(C) which are used practically in distribution network.

- **a.** Qusaiba-Al-Dawaa 33kv feeder which protected by circuit breaker in Qusaiba 33kv bus bar with its over current relay. Tables(4), (5), shows the parameters for (I.D.M.T.) relay and operating time for 3- phase fault and earth fault (E/F) respectively. To represent the points of TCC curves assuming load current increase 110% from pickup current at beginning point and the fault current in Qusaiba, Sayloo and Dawaa as the other points in curves.

Table(4) Parameters and Operating Timefor Over Current Relay (3-phase fault & instantaneous) in C.B. of Qusaiba S.S. Without DG		
TMS = 0.3 PS = 6.33 Ipu = 760A C.T.ratio = 600/5		
Fault locations	**L-L-L Fault current(A)**	**Operating Time(second)**
110% Ipu	836	22.012
Dawaa B.B	2431	1.787
Sayloo B.B	2964	1.523
Qusaiba B.B	8241	0.860
Instantaneous : Ipu = 4200 Delay Time = 0.06 sec.		

Table(5) Parameters and Operating Timefor Over Current Relay (E/F & instantaneous) in C.B. of Qusaiba S.S. Without DG		
TMS = 0.1 PS = 0.2 Ipu = 24A C.T.ratio = 600/5		
Fault locations	**L-G Fault current(A)**	**Operating Time(second)**
110% Ipu	26.4	7.337
Dawaa B.B	191	0.331

Sayloo B.B	197	0.326
Qusaiba B.B	215	0.312
Instantaneous : Ipu = 120A Delay Time = 0.06 sec.		

Figure (4) represent(TCC) curves in Log-Log paper illustrate operating time for over current relays in different values and locations (points in Tables(4), (5) above), three phase fault in phase protection and earth faults(E/F) for ground protection, also shows the information for relays used.

Aswell Figure(5) shows the instantaneous feature that makes the relays operating time will be set as(600 ms) when fault exceed (4200A) for three phase fault and(120A) for earth fault, these values represent 50% maximum faults currently approximately, all values will be instantaneous operating.

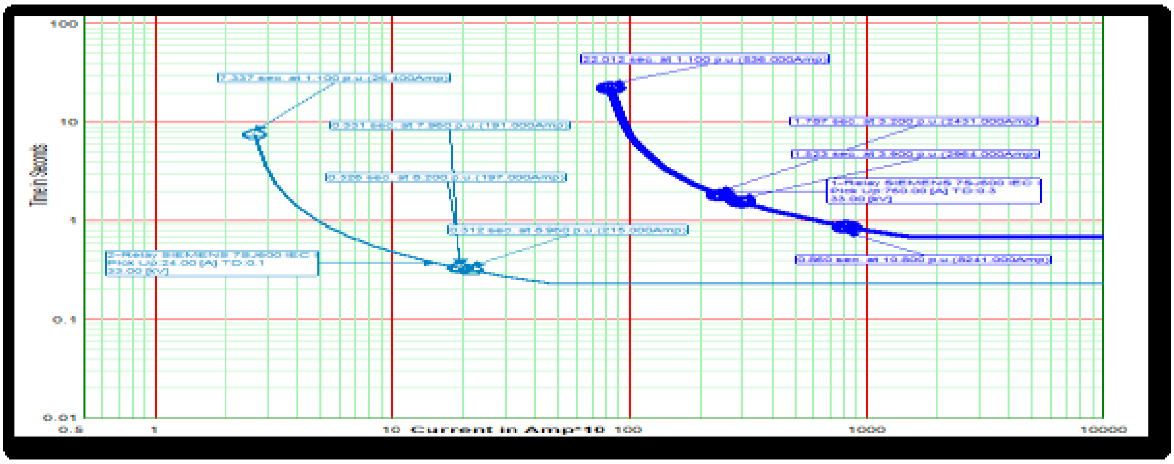


Figure (4) :Time Current Characteristic (TCC) Curves for Qusaiba S.S. O/C (3-phase fault&E/F) Relays Without DG

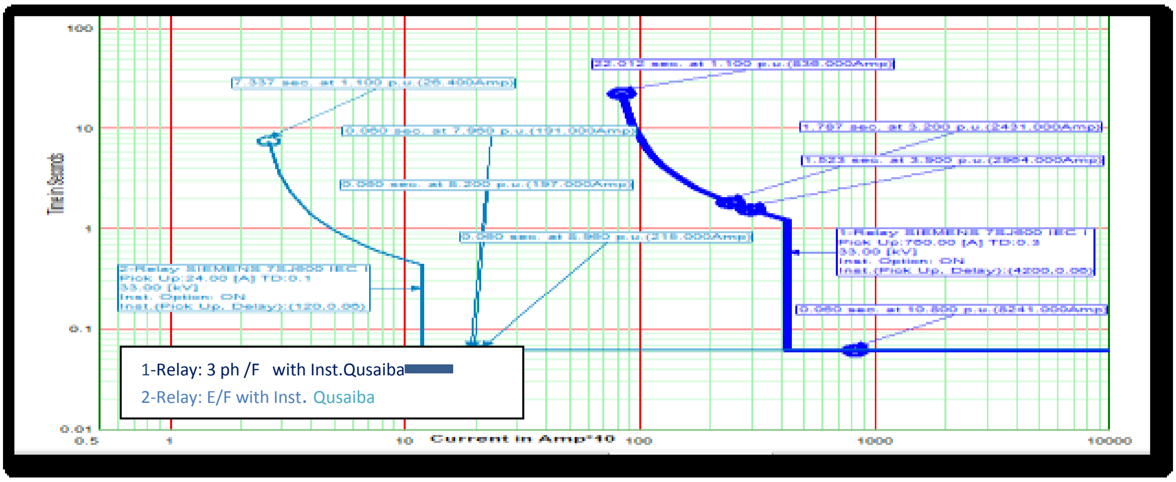


Figure (5) :Time Current Characteristic (TCC) Curves Qusaiba S.S. O/C(3-phase fault&E/F)Relays With instantaneous (Without DG)

b. Qusaiba-Al-Zaafraniya 33kv feeder which protected through circuit breaker in Qusaiba 33kv bus bar with its over current relay. Tables(6), (7), shows the parameters for this relays and operating time, Assuming load current increase 110% from pickup current at beginning point and the fault current in Qusaiba, Zaafraniya and ten times from pickup current (10*Ipu) as the other points in curves.

Table (6) Parameters and Operating Timefor Over Current Relay (3-phase fault & instantaneous) in C.B. of Qusaiba S.S. Without DG		
TMS = 0.3 PS =5.5 Ipu = 660A C.T.ratio = 600/5		
Fault locations	**L-L-L Fault current(A)**	**Operating Time(second)**
110% Ipu	726	22.012
Zaafraniya B.B	4214	1.112
10* Ipu B.B	6600	0.891
Qusaiba B.B	8241	0.811
Instantaneous : Ipu = 4200	**Delay Time = 0.06 sec.**	

Table(7) Parameters and Operating Timefor Over Current Relay (E/F & instantaneous) in C.B. of Qusaiba S.S. Without DG		
TMS = 0.1 PS = 0.2 Ipu = 24A C.T.ratio = 600/5		
Fault locations	**L-G Fault current(A)**	**Operating Time(second)**
110% Ipu	26.4	7.337
Zaafraniya B.B	202	0.322
10*Ipu B.B	209	0.317
Qusaiba B.B	215	0.312
Instantaneous : Ipu = 120A	**Delay Time = 0.06 sec.**	

Figures (6), (7) presented (TCC) curves for over current relay with different magnitudes of three phase faults and earth faults, operating time, relay performance also illustrated.

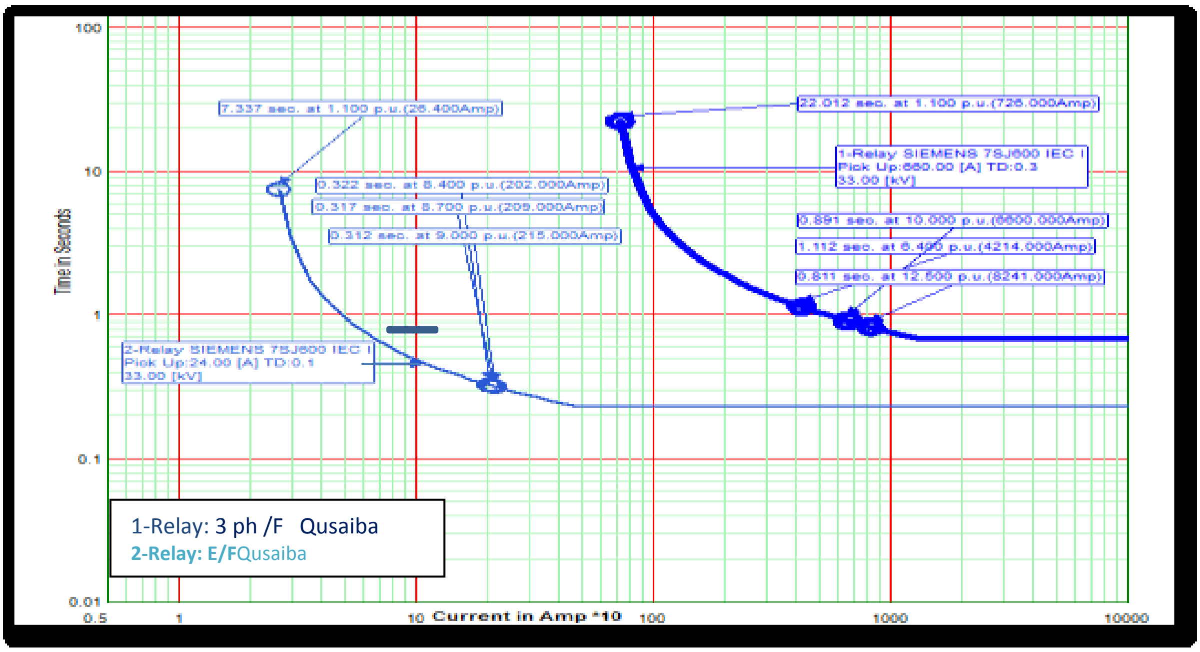


Figure (6):Time Current Characteristic (TCC) Curves for Qusaiba S.S.O/C (3-phase fault &E/F) Relays Without DG

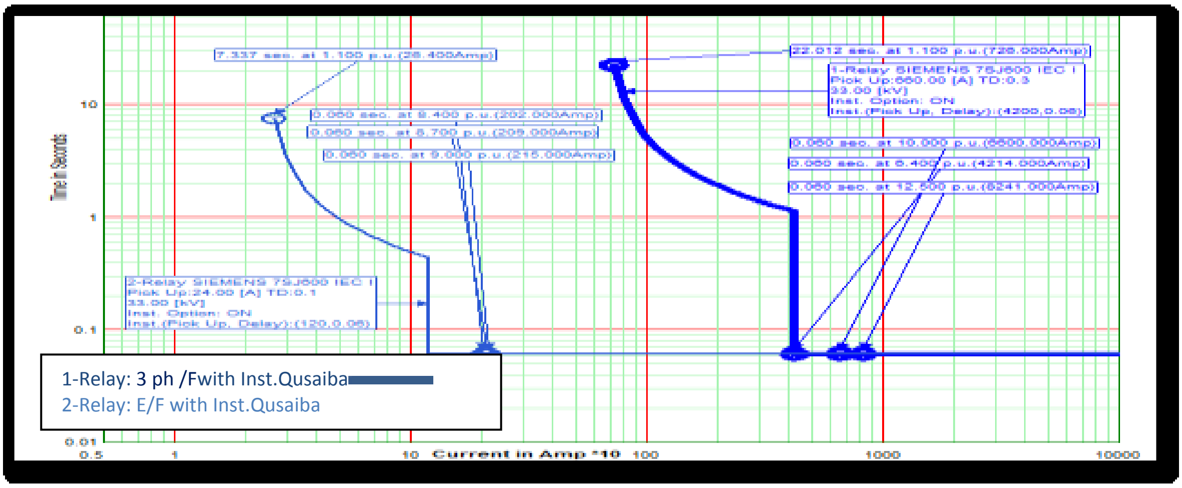


Figure (7) :Time Current Characteristic (TCC) Curves Qusaiba S.S. O/C(3-phase fault&E/F)Relays With instantaneous (Without DG)

Case (2) Embedded Two Distributed Generation (25MW) Near Al-Dawaa and Al-Zaafraniya 33/11 KV Substations:

In case of penetrate the optimal number, location and size DGs to the 33 KV network. Tables (8), (9), (10), (11), (12), (13) illustrate the setting parameters and the operating time results to the over current protection relays (3-phase fault and E/F with instantaneous) in Qusaiba, Al-Dawaa and DG station circuit breakers respectively when two DG with (25MW) for each one embedded near the load buses of Al-Dawaa and Al- Zaafraniya 33/11 KV substations which is represent the optimal locations to south of Al-Rusafa 33 KV network.

Table(8) Parameters and Operating Timefor Over Current Relay (3-phase fault& instantaneous) in C.B. of Qusaiba S.S. With Two DG

TMS = 0.55 PS = 4 Ipu = 480A C.T.ratio = 600/5		
Fault locations	**L-L-L Fault current(A)**	**Operating Time(second)**
110% Ipu	528	40.356
Dawaa B.B.	4054	1.767
Qusaiba B.B.	10725	1.247
Instantaneous : Ipu = 5400A	**Delay Time = 0.05 sec.**	

Table(9) Parameters and Operating Timefor Over Current Relay (E/F & instantaneous) in C.B. of Qusaiba S.S. With Two DG

TMS = 0.2 PS = 0.4 Ipu = 48A C.T.ratio = 600/5		
Fault locations	**L-G Fault current(A)**	**Operating Time(second)**
110% Ipu	٥٢.٨	١٤.٦٧٥
Dawaa B.B.	٥٣٣	0.568
Qusaiba B.B.	٦٠٤	0.539
Instantaneous : Ipu = 300A	**Delay Time = 0.05 sec.**	

Table(10) Parameters and Operating Time for Over Current Relay (3-phase fault & instantaneous) in C.B. of Dawaa S.S With Two DG

TMS = 0.3 PS = 2.5 Ipu =300A C.T.ratio = 600/5		
Fault locations	**L-L-L Fault current(A)**	**Operating Time (second)**
110% Ipu	**٣٣٠**	**22.012**
Dawaa B.B.	**4054**	**0.786**
Qusaiba B.B.	**10725**	**0.680**
Instantaneous :	**Ipu = 2040A**	**Delay Time = 0.05 sec.**

Table(11) Parameters and Operating Timefor Over Current Relay(E/F & instantaneous) in C.B. of Dawaa S.S With Two DG		
TMS = 0.1 PS = 0.3 Ipu = 36A C.T.ratio = 600/5		
Fault locations	**L-G Fault current(A)**	**Operating Time(second)**
110% Ipu	39.6	7.337
Dawaa B.B.	٥٣٣	0.253
Qusaiba B.B.	٦٠٤	0.241
Instantaneous : Ipu = 240A Delay Time = 0.05 sec.		

Table(12) Parameters and Operating Timefor Over Current Relay (3-phase fault& instantaneous) in C.B. of DG Station Near Dawaa S.S.		
TMS = 0.4 PS = 4 Ipu =480A C.T.ratio = 600/5		
Fault locations	**L-L-L Fault current(A)**	**Operating Time(second)**
110% Ipu	528	29.350
DG station	٤٠٢٩	١.٢٨٩
Dawaa B.B.	4054	١.٢٨٥
Instantaneous : Ipu = 2400A Delay Time = 0.06 sec.		

NOTE:

- Appendix(D) shows Figures (10), (11), (12), (13)
- All protected schemes data are practically used in Rusafa distribution network according to Iraqi MOE.

Table(13) Parameters and Operating Time for Over Current Relay (E/F & instantaneous) in C.B. of DG Station Near Dawaa S.S.		
TMS = 0.2 PS = 0.3 Ipu = 36A C.T.ratio = 600/5		
Fault locations	**L-G Fault current(A)**	**Operating Time (second)**
110% Ipu	**39.6**	**14.675**
DG station	**٥٣٢**	**0.506**
Dawaa B.B.	**٥٣٣**	**0.506**
Instantaneous : Ipu = 264A Delay Time = 0.06 sec.		

Figures (8),and (9) represent the (TCC) curves which is shows the coordination in operating timebetween the over current relays against the faults. This coordination satisfies DG continued to supply the load when the utility network is separated during faults. The short circuit current magnitude with two DGs increases more than its magnitude in cases without DG, so it makes (TMS) will be increase. The pickup current will be reducing from utility source because the DGs supplied part of loads. These two changes effect on the setting and coordination. Tables (14), (15), (16), (17), (18), (19) shows the setting parameters and the operating timeresults to the over current protection relays (3-phase fault and E/F with instantaneous) in Qusaiba, Al-Zaafraniya and DG station circuit breakers respectively when two DG (25MW) embedded near the load buses of Al-Dawaa and Al- Zaafraniya 33/11 KV substations which is represent the optimal locations to south of Al-Rusafa 33 KV network.

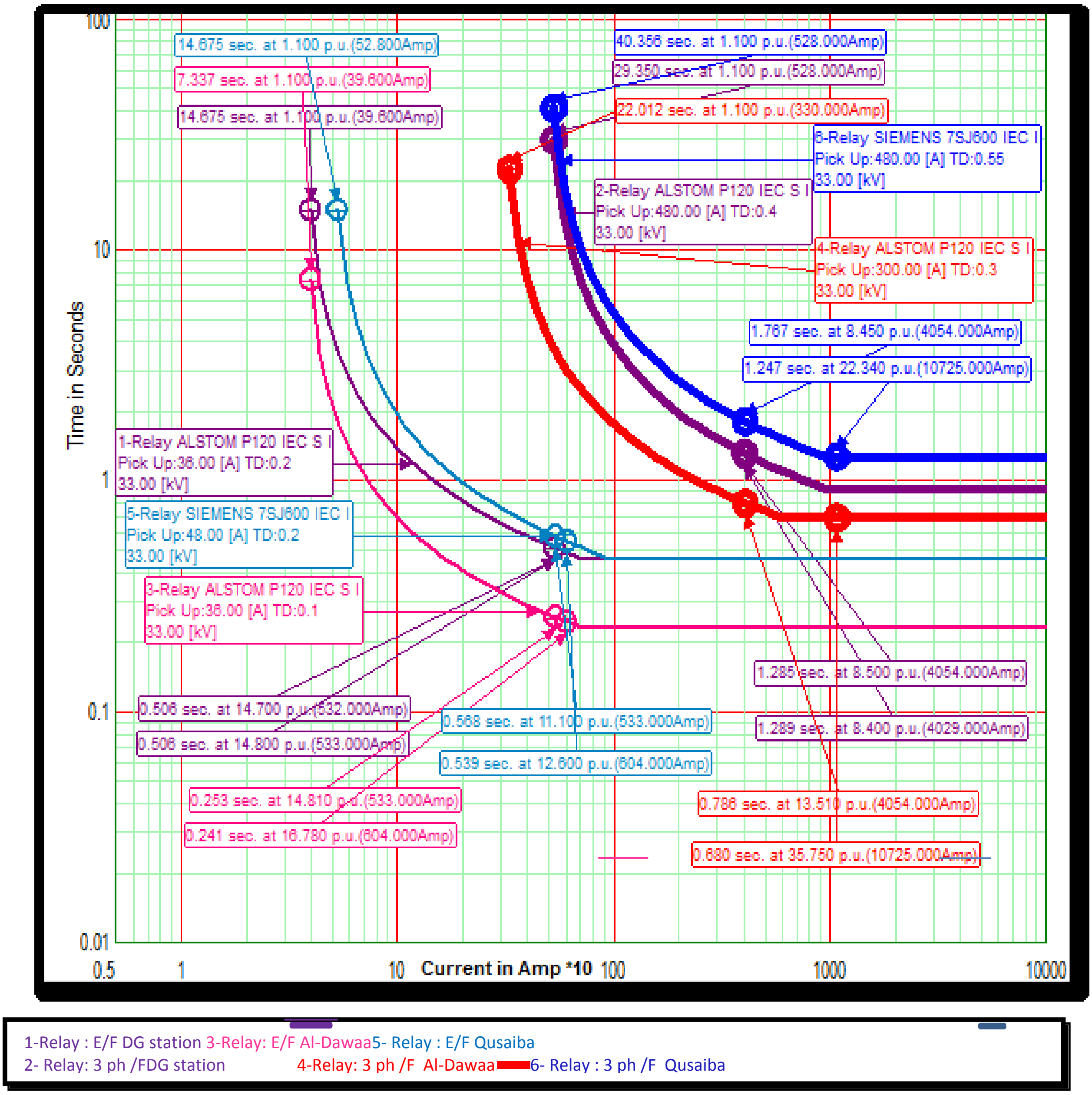


Figure (8) :Time Current Characteristic (TCC) Curves Qusaiba, Dawaa and DG station O/C (3-phase fault&E/F) Relays With Two DG

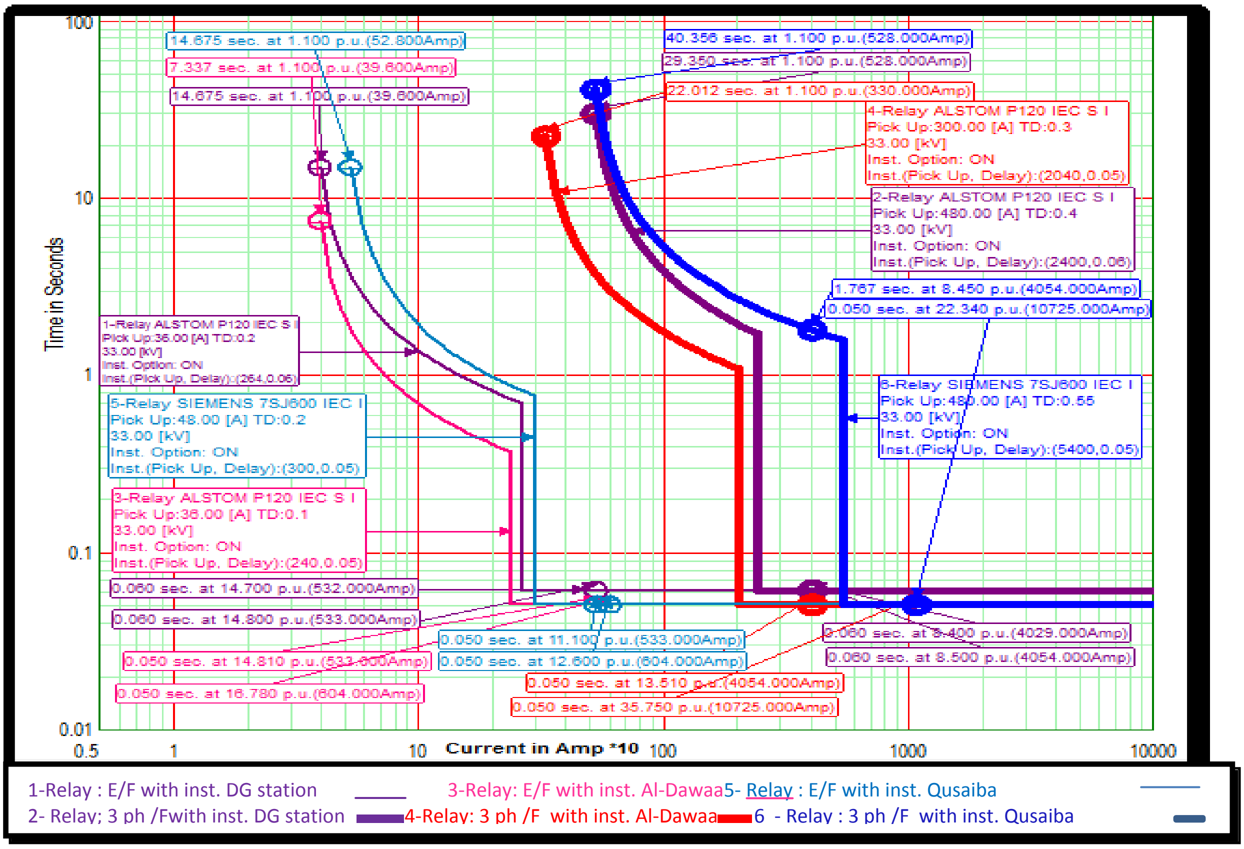


Figure (9) :Time Current Characteristic (TCC) Curves for Qusaiba, Dawaa and DG station O/C(3-phase fault&E/F)Relays With instantaneous (With Two DG)

Table(14) Parameters and Operating Timefor Over Current Relay (3-phase fault& instantaneous) in C.B. of Qusaiba S.S. With Two DG

TMS = 0.6 PS = 2	Ipu = 180A C.T.ratio = 600/5	
Fault locations	**L-L-L Fault current(A)**	**Operating Time(second)**
110% Ipu	198	44.025
Zaaf. B.B.	6055	1.380
Qusaiba B.B.	10725	1.380
Instantaneous :	**Ipu = 5400A**	**Delay Time = 0.05 sec.**

Table(15) Parameters and Operating Timefor Over Current Relay (E/F & instantaneous) in C.B. of Qusaiba S.S. With Two DG

TMS = 0.2 PS = 0.4	Ipu = 48A C.T.ratio = 600/5	
Fault locations	**L-G Fault current(A)**	**Operating Time(second)**
110% Ipu	52,8	14,675
Zaaf. B.B.	566	0.554
Qusaiba B.B.	604	0.539
Instantaneous :	**Ipu = 300A**	**Delay Time = 0.05 sec.**

Table(16) Parameters and Operating Timefor Over Current Relay (3-phase fault& instantaneous) in C.B. of Zaaf. S.S With Two DG

TMS = 0.3 PS = 2	Ipu =240A C.T.ratio = 600/5	
Fault locations	**L-L-L Fault current(A)**	**Operating Time(second)**
110% Ipu	264	22.012
Zaaf. B.B.	6055	0.680
Qusaiba B.B.	10725	0.680
Instantaneous :	**Ipu = 3000A**	**Delay Time = 0.05 sec.**

Table(17) Parameters and Operating Timefor Over Current Relay (E/F & instantaneous) in C.B. of Zaaf. S.S With Two DG		
TMS = 0.1 PS = 0.3 Ipu = 36A C.T.ratio = 600/5		
Fault locations	**L-G Fault current(A)**	**Operating Time(second)**
110% Ipu	39.6	7.337
Zaaf. B.B.	566	0.247
Qusaiba B.B.	604	0.241
Instantaneous : Ipu = 240A Delay Time = 0.05 sec.		

Table(18) Parameters and Operating Timefor Over Current Relay (3-phase fault& instantaneous) in C.B. of DG Station Near Zaaf. S.S.		
TMS = 0.4 PS = 4 Ipu =480A C.T.ratio = 600/5		
Fault locations	**L-L-L Fault current(A)**	**Operating Time(second)**
110% Ipu	528	29.350
DG station	5954	1,084
Dawaa B.B.	6055	1,077
Instantaneous : Ipu = 3000A Delay Time = 0.06 sec.		

Table(19) Parameters and Operating Timefor Over Current Relay (E/F & instantaneous) in C.B. of DG Station Near Zaaf. S.S.		
TMS = 0.2 PS = 0.3 Ipu = 36A C.T.ratio = 600/5		
Fault locations	**L-G Fault current(A)**	**Operating Time(second)**
110% Ipu	39.6	14.675
DG station	565	0.495
Dawaa B.B.	566	0.494
Instantaneous : Ipu = 240A Delay Time = 0.06 sec.		

Figures (10), (11) represented the (TCC) curves, the increases in short circuit current after two DG are embedded in 33KV network, for Qusaiba over current relay(I.D.M.T.) in 3-phase faults, lead to (TMS) increase to (0.6) compares to(0.3) in case without DGand for (E/F) increase to (0.2) compares to(0.1)for without DG. But the pickup current will be decrease to(180A) with two DGs compares to (660A) without DG, because DGs supplied a large part of loads and the load current will be little from utility source lead to mal-coordination between primary and backup protection.

Figure (12) above represented the (TCC) curves with coordination curves through assuming current multiplier is (3.67) to re-coordinate the over current protection relay of Qusaiba circuit breaker for 33KV feeder supplied Al-Zaafraniya loads, the pickup current will increased to be the same as in case without DG (660A) instead of (180A) with two DG. But, we should pay attention to the pickup current of instantaneous time of operation situation. It must be set as (1473A) instead of (5400A) taking into consideration the current multiplier above to stay on the same setting.

Figure (13) represented the (TCC) curves after re-coordination, it is clear the over current protection relays (3-phase faultand E/F) for Zaafraniya 33KV circuit breaker will be operate fist when three phase faults and earth faults occur in the zone between Qusaiba and Zaafraniya and then Qusaiba over current relay will be operate to separate the feeder and clear the fault

CONCLUSIONS

The conclusions obtained from this work can be summarized as follows:

1. In radial distribution system, utilization many DGs with optimal number, location and size are better than use one DG alone.
2. To choose the optimal locations, there are geographical and environmental constraints depend on the nature of electric distribution network and its location with respect to the city center, these constraints effect on the availability of appropriate area to construct DG power plants.

3. DGs penetrated will effect on over current protection relays (phase and ground) settings during disturbance, like sudden increase in loads or during three phase and earth fault issues which leads to increase in short circuit current and then mal-coordination between primary and backup over current relays.
4. Maximum load current from utility supply reduced when DGs embedded to the network to the fact that a great part of loads will be powered from DG, the pickup current will effect in the utility side which cause intersection in time of operation, so it is necessary to reset the affected over current relays, the optimal setting in some situations is take the pickup current in case without DG.
5. In general the Time Setting Multiplier (TMS) must be increase after DG penetrated.
6. Because DG station almost be close to load bus substation, the parameter of overcurrent relays will be convergent.
7. Concentricity on activate instantaneous feature in over current protection relays to avoid the risks from high current faults.

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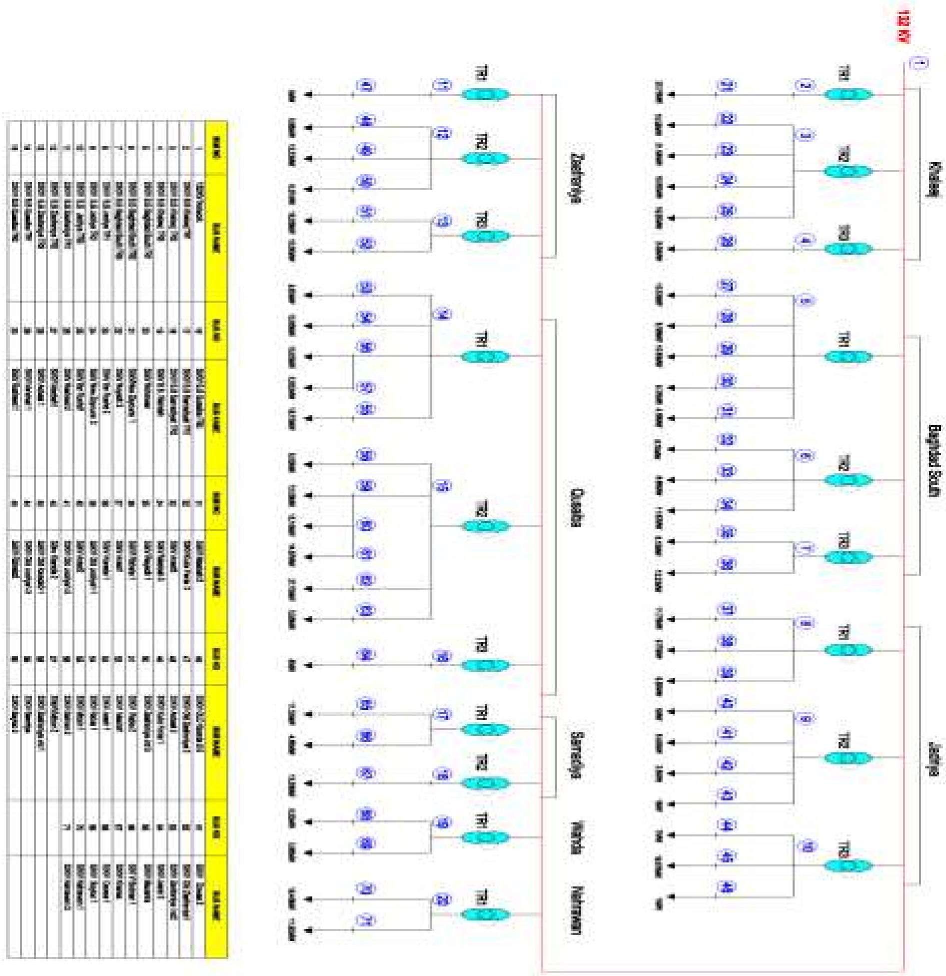
APPENDIX (A)

Data Base for South of Al-Rusafa 33KV Distribution NetworkTaken From Ministry of Electricity (MOE) in Iraq

From Bus	To Bus	R P.U.	X P.U	PL MW	QL Mvar	From Bus	To Bus	R P.U.	X P.U	PL MW	QL Mvar
1	2	0.00	0.18	0	0	8	37	0.06	0.05	11.75	7.282
1	3	0.00	0.18	0	0	8	38	0.034	0.0643	9.75	6.043
1	4	0.00	0.18	0	0	8	39	0.03	0.025	9.5833	5.9392
1	5	0.00	0.18	0	0	9	40	0.06	0.05	5	3.1
1	6	0.00	0.18	0	0	9	41	0.03	0.025	6.75	4.183
1	7	0.00	0.18	0	0	9	42	0.034	0.0643	2.6	1.611
1	8	0.00	0.18	0	0	9	43	0.035	0.03	1	0.62
1	9	0.00	0.18	0	0	10	44	0.035	0.03	7	4.34
1	10	0.00	0.18	0	0	10	45	0.036	0.069	19.67	12.19
1	11	0.00	0.18	0	0	10	46	0.035	0.03	1	0.62
1	12	0.00	0.18	0	0	11	47	0.017	0.032	9	5.58
1	13	0.00	0.18	0	0	12	48	0.0705	0.01355	6.667	4.138
1	14	0.00	0.18	0	0	12	49	0.027	0.0514	15.333	9.5
1	15	0.00	0.18	0	0	12	50	0.058	0.049	6.517	4.04
1	16	0.00	0.18	0	0	13	51	0.017	0.032	16.28	10.09
1	17	0.00	0.18	0	0	13	52	0.0096	0.0184	10.667	6.61
1	18	0.00	0.18	0	0	14	53	0.035	0.03	9.833	6.094
1	19	0.00	0.18	0	0	14	54	0.0955	0.01842	15.667	9.71
1	20	0.00	0.18	0	0	14	55	0.176	0.3384	18.75	11.62
2	21	0.0174	0.033	23.75	14.72	14	56	0.111	0.2134	10.83	6.712
3	22	0.0183	0.035	10.58	6.557	56	57	0.066	0.126	0.833	0.516
3	23	0.0082	0.0156	21.58	13.374	15	58	0.116	0.099	9.65	5.98
3	24	0.0174	0.033	16.83	10.43	15	59	0.045	0.087	13.083	8.11
3	25	0.0082	0.0156	19.25	11.93	59	60	0.1825	0.2443	5.167	3.2
4	26	0.0275	0.0523	6.083	3.77	60	61	0.079	0.0115	14.67	9.092
5	27	0.0232	0.02	10.533	6.53	15	62	0.098	0.1884	27.75	17.2
5	28	0.0327	0.063	6.583	4.08	15	63	0.116	0.099	0.583	0.361
5	29	0.039	0.074	10.5	6.5	16	64	0.035	0.03	8	5
5	30	0.0087	0.0165	9.333	5.78	17	65	0.29	0.247	11.333	7.024
5	31	0.0232	0.02	4.583	2.84	17	66	0.174	0.148	4.6667	2.892
6	32	0.0246	0.047	6.75	4.18	18	67	0.13	0.25	13.583	8.42
6	33	0.06	0.05	8.667	5.37	19	68	0.039	0.075	9.333	5.78
6	34	0.0232	0.02	11.62	7.21	19	69	0.078	0.15	5.6667	3.512
7	35	0.006	0.011	6.167	3.822	20	70	0.185	0.35	18.467	11.444
7	36	0.0145	0.0276	12.333	7.64	20	71	0.185	0.35	11.92	7.387



South of Al-Rusafa 33kV distribution network

APPENDIX (B)

ANSI/IEEE and IEC constants for standard overcurrent relays

Curve description	Standard	α	β	*L*
Moderately inverse	IEEE	0.02	0.0515	0.114
Very inverse	IEEE	2.0	19.61	0.491
Extremely inverse	IEEE	2.0	28.2	0.1217
Inverse	CO8	2.0	5.95	0.18
Short-time inverse	CO2	0.02	0.0239	0.0169
Standard inverse	IEC	0.02	0.14	0
Very inverse	IEC	1.0	13.5	0
Extremely inverse	IEC	2.0	80.0	0
Long-time inverse	UK	1.0	120	0

APPENDIX (C)

Relays Types and Specifications

For Qusaiba: Phase Fault (50 , 51) SIEMENS 7Sj600 IEC I, E/F (50N , 51N) SIEMENS 7Sj600 IEC I
For Dawaa, Zaafraniya and DG stations :Phase Fault (50 , 51) ALSTOM P120 IEC SI, E/F (50N , 51N) ALSTOM P120 I

APPENDIX(D)

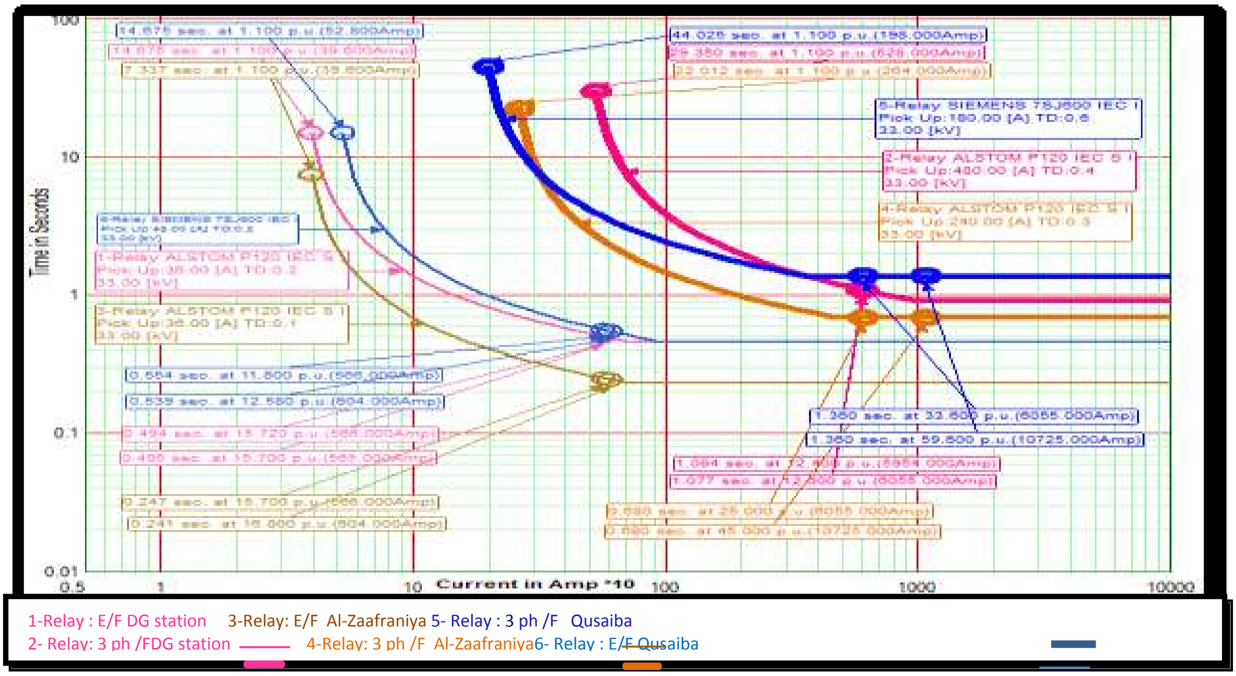


Figure (10) :Time Current Characteristic (TCC) Curves Qusaiba, Zaafr. and DG station O/C (3-phase fault&E/F) Relays Two With DG

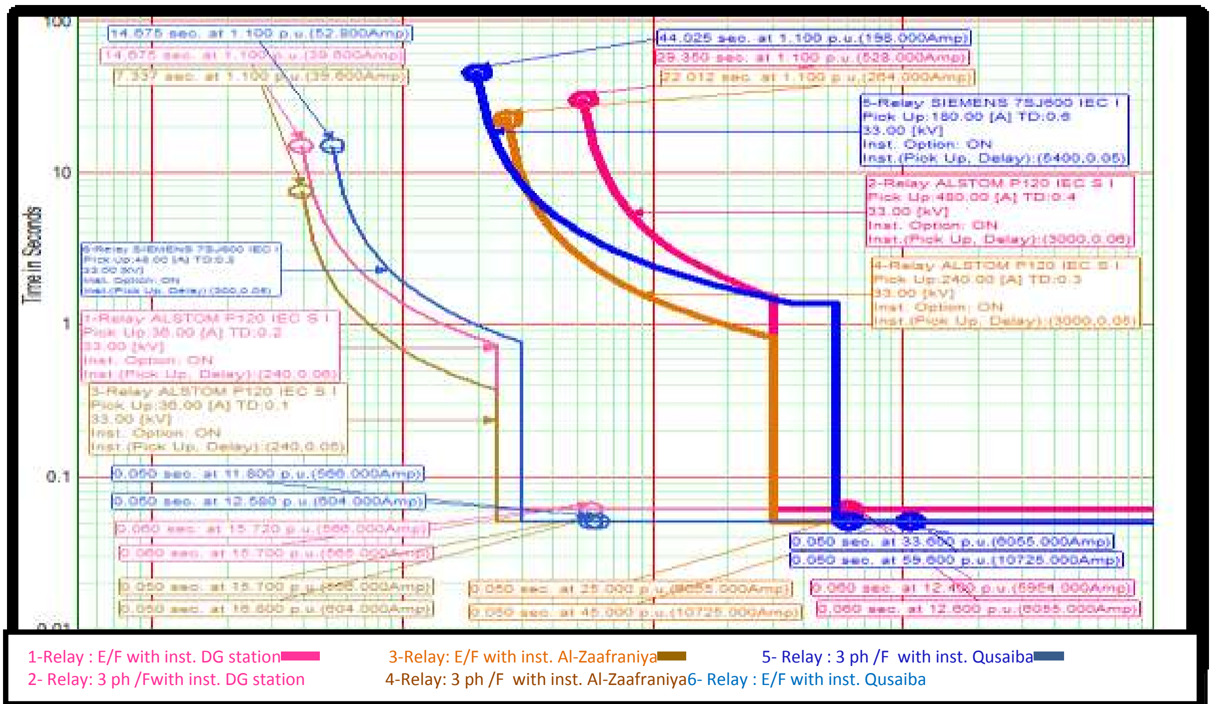


Figure (11) :Time Current Characteristic (TCC) Curves for Qusaiba, Zaafraniya and DG station O/C(3-phase fault&E/F)Relays With instantaneous (With Two DG)

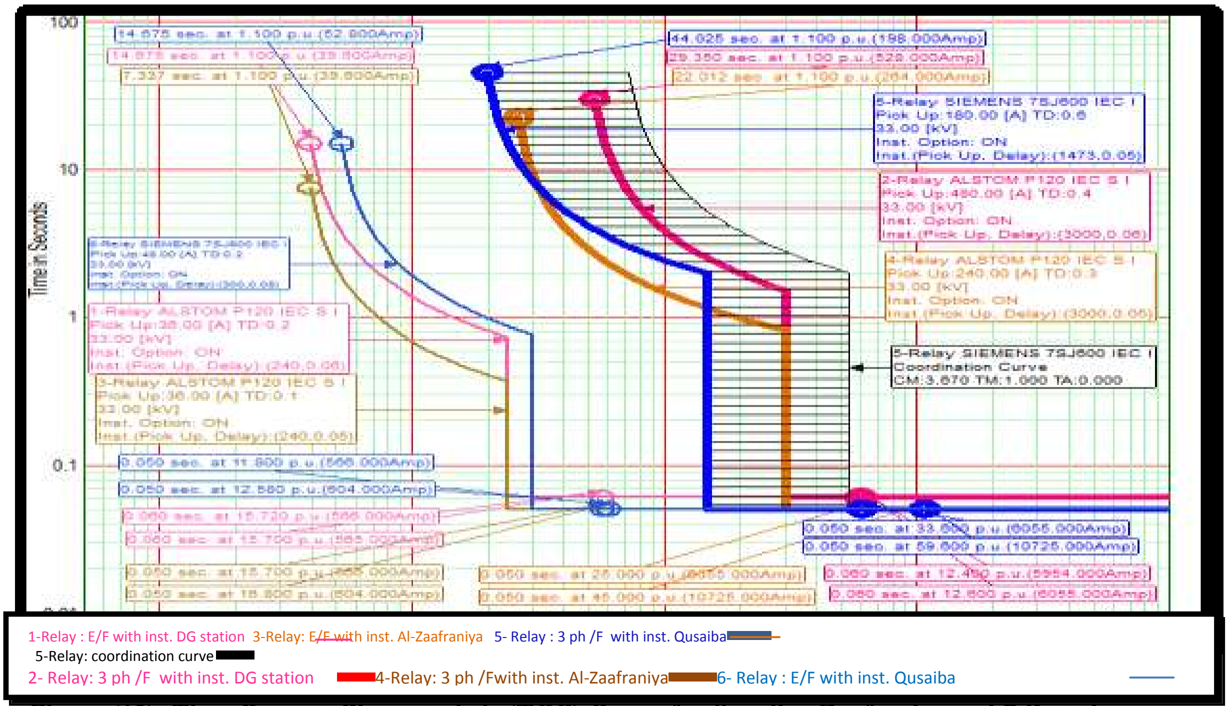


Figure (12) :Time Current Characteristic (TCC) Curvesfor Qusaiba, Zaafraniya and DG station O/C (3-phase fault&E/F)Relays With instantaneous (With Coordination Curve)

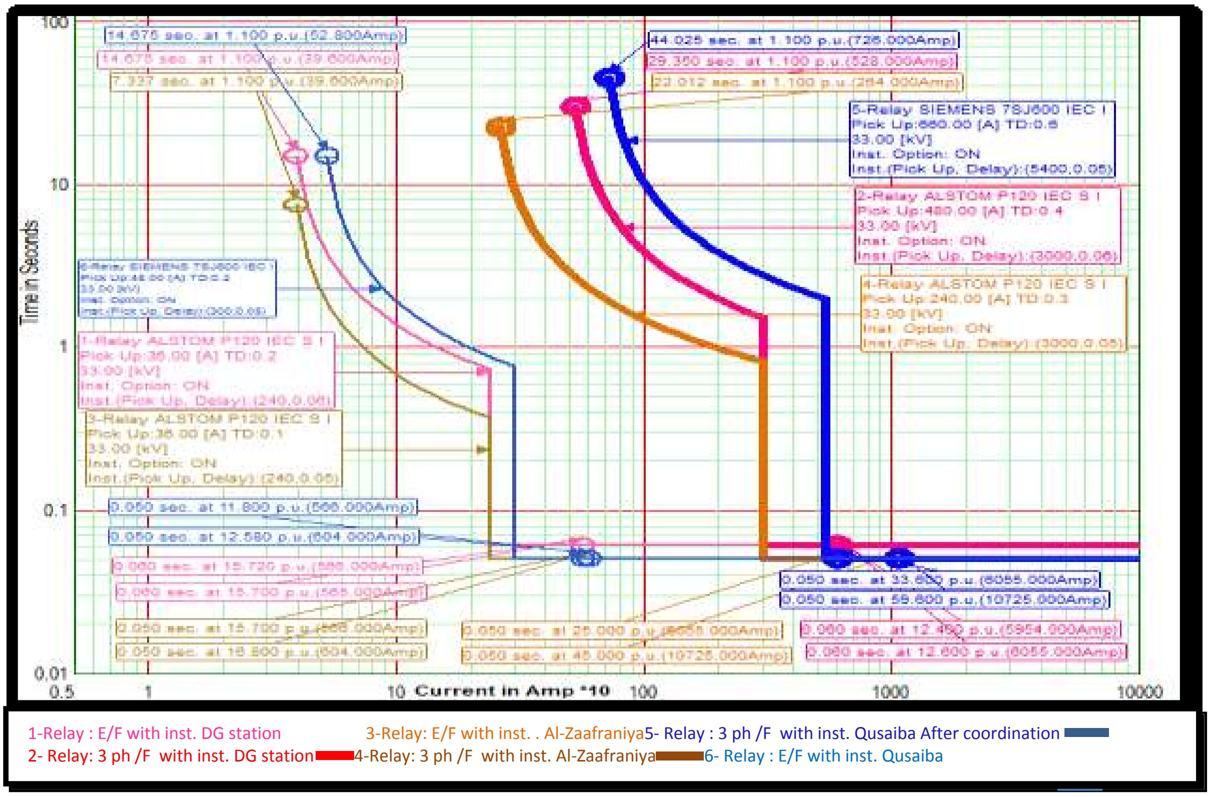


Figure (13) :Time Current Characteristic (TCC) Curvesfor Qusaiba, Zaafraniya and DG station O/C (3-phase fault&E/F)Relays With instantaneous after Re-Coordination