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Thermal Limit Reduction and Power Quality Improvement Adopting Microgrid Strategy on the Distributed Network: Iraq as a Case Study

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ABSTRACT

This paper, a microgrids was analyzed, designed and simulated for Holy Karbala Distribution Network by using (MATLAB 2014 a) program to reduce the thermal Limit factor for the transmission lines and to enhance the power quality for the distribution network. Two microgrids was located at the substations which has a thermal limit more than one these substations are Al-Hindia and Al-Hussainia, the addition of microgrid reduce the thermal limit on Al-Hindia SS from (1.519 to o.78)and on Al-Hussainia SS from (1.1036 to 0.67). In addition, the power quality was improved for the overall the city from the consumer point of view.

KEYWORDS: Thermal Limit Factor (TLF), power quality, microgrid, distributed network.

INTRODUCTION

Microgrids (MG) are small grouping of interconnected power generation and control technologies that can operate within or independent of a central grid and can satisfy customer requirements, such as local reliability enhancement, feeder loss reduction, local voltage regulation and increasing efficiency through the use of waste heat [1].

Holy Karbala Distribution Network:

Holy Karbala distribution network is connected to the Iraqi power grid at Al-Mussayab bus bar to the southeast of Holy Karbala city, there is another connection at Baghdad bus bar.

Holy Karbala distribution network consists of six transformers substations transform the high voltage (132 KV) to the medium voltage (33 and 11 KV). They are shown as follows:

- Three substations each substation contains three transformers of 132/33/11 KV.
- Three substations each substation contains two transformers of 132/33 KV.
- Eleven substations each substation contains two transformers of 33/11 KV.
- One substation contain three transformers of 33/11 KV.

These substations are shown diagrammatically in Figure (1) , the bus data and line data of system are given in tables (1) and (2).

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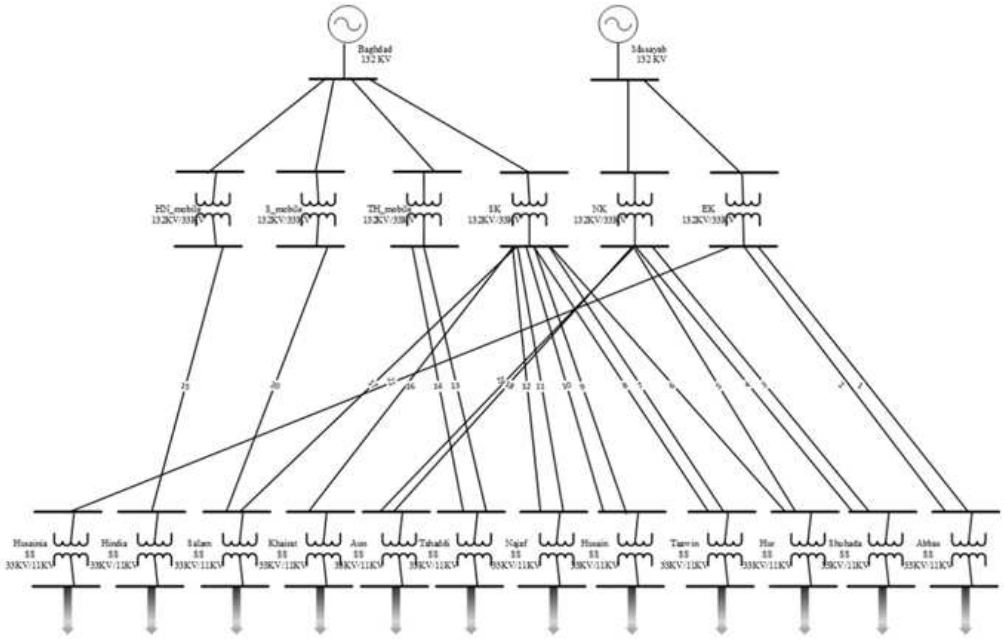

Fig. 1: Simplified diagram for Holy Karbala distribution network

Table 1: Bus data of Holy Karbala distribution system

Bus NO.	Station Name	V P.U.	δ Degree	P_L MW	Q_L Mvar
1	East Karbala	1	0	0	0
2	North Karbala	-	-	0	0
3	South Karbala	-	-	0	0
4	Al-Tahaddy mobile	-	-	0	0
5	Al-Salam mobile	-	-	0	0
6	Al-Hindia mobile	-	-	0	0
7	Abbas SS	-	-	34.8	16.85
8	Shuhadaa SS	-	-	44.4	13.3
9	Al-Hur SS	-	-	13.3	6.483
10	Al-Taawin SS	-	-	29.1	14.065
11	Al-Hussain SS	-	-	23.1	11.165
12	Al-Najaf SS	-	-	34.3	16.578
13	Al-Tahaddy SS	-	-	32.2	16.563
14	Al-Hindia SS	-	-	43.08	20.822
15	Khairat SS	-	-	21.3	10.295
16	Al-Salam SS	-	-	41.8	20.203
17	Aun SS	-	-	23.33	11.271
18	Al-Hussainia SS	-	-	31.3	15.128

Table 2: Line data of Holy Karbala distribution system

Line No.	From Bus	To Bus	R (P.U)	X (P.U)
1	1	7	1.205	3.146
2	1	7	1.405	3.668
3	2	8	1.147	2.996
4	2	8	0.557	1.455
5	2	9	0.451	1.178
6	3	9	0.874	2.282
7	3	10	0.436	1.138
8	3	10	0.436	1.138
9	3	11	0.195	0.511
10	3	11	0.195	0.510
11	3	12	0.354	0.925
12	3	12	0.355	0.927
13	4	13	0.130	0.340
14	4	13	0.131	0.341

15	6	14	0.058	0.153
16	3	15	0.261	0.683
17	5	16	0.503	1.315
18	3	16	0.505	1.320
19	2	17	0.212	0.554
20	2	17	0.212	0.554
21	1	18	1.175	3.066

Thermal limit of transmission lines:

The power handling ability of a line is limited by the thermal loading limit and the stability limit. The increase in the conductor temperature, due to the real power loss, stretches the conductors. This will increase the sag between transmission towers. At higher temperatures this may result in irreversible stretching. The thermal limit is specified by the current-carrying capacity of the conductor and is available in the manufacturer's data. If the current-carrying capacity is denoted by $I_{thermal}$ the thermal loading limit of a line is [2].

$$S^{L}_{thermal} = 3 * V_{\phi rated} * I_{thermal} \quad (1)$$

Where thermal limit factor (TLF) will be as:

$$TLF = \frac{\text{line flow } (S_{ij})}{S^{L}_{thermal}} \quad (2)$$

Where S ij is calculated by using power flow algorithm.

Thermal limit factor (TLF) gives a percentage of each line if this ratio exceeds (1) it means the line is out of limit.

Power Quality at the Distributed Network:

The power quality at the end-user level defined as "any power problem manifested in voltage, current, or frequency deviations that results in failure or missed operation of utility or end user equipment". Those of the common used indexes by utility companies, which represent the reliability level, are namely System Average Interruption Duration Index (SAIDI), System Average Interruption Frequency Index (SAIFI), and Customer Average Interruption Duration Index (CAIDI). SAIDI is the average outage duration for each customer served. SAIDI is measured in units of time, often minutes. It is usually measured over the course of a year [3].

$$SAIDI = \frac{\text{Total duration of customer interruption}}{\text{Total number of customers served}} \quad (3)$$

SAIFI is the average number of interruptions that a customer would experience. SAIFI is measured in units of interruptions per customer. It is also typically measured over the course of a year.

$$SAIFI = \frac{\text{Total number of curtomer interruptions}}{\text{Total number of customers served}} \quad (4)$$

CAIDI is the Customer Average Interruption Duration Index and is described as:

$$CAIDI = \frac{\text{Total duration of customer interruptions}}{\text{Total number of customer interruptions}} = \frac{SAIDI}{SAIFI} \quad (5)$$

RESULTS AND DISCUSSION

a. Thermal Limit Factor (THF) results:

The thermal limit for the transmission lines of Holy Karbala distributed network results are listed in table (3).

Table 3: Thermal limit for Holy Karbala distribution network

Line	Line location From 132/33 KVSS-To 33/11KV SS	Thermal limit Factor (TLF)
1	East Karbala-Abbas SS	0.6137
2	East Karbala-Abbas SS	0.6137
3	North Karbala-Shuhadaa SS	0.7828
4	North Karbala-Shuhadaa SS	0.7828
5	North Karbala-Al-Hur SS	0.2349
6	South Karbala-Al-Hur SS	0.2349
7	South Karbala-Al-Taawin SS	0.4619
8	South Karbala-Al-Taawin SS	0.4619
9	South Karbala-Al-Hussain SS	0.4072
10	South Karbala-Al-Hussain SS	0.4072
11	South Karbala-Al-Najaf SS	0.6047
12	South Karbala-Al-Najaf SS	0.6047
13	Al-Tahaddy mobile-Tahaddy SS	0.5691
14	Al-Tahaddy mobile-Tahaddy SS	0.5691
15	Al-Hindia mobile-Al-Hindia SS	1.519
16	South Karbala-Khairat SS	0.7511
17	Al-Salam mobile-Al-Salam SS	0.736

18	South Karbala-Al-Salam SS	0.736
19	North Karbala-Aun SS	0.4113
20	North Karbala-Aun SS	0.4113
21	East Karbala-Al-Hussainia SS	1.1036

It is clear that the thermal limit of the lines (15 and 21) is exceed one ,so; it required to decrease the loads that it fed by this lines to decrease TLF these overloads are selected to be the normal loads for the microgrids, as shown in table (4) .

Table 4: Thermal limit for Holy Karbala distribution network after decreasing loads on Al-Hindia and Al-Hussainia substations

Line	Line location From 132/33 KVSS-To 33/11KV SS	% Decreased load	Thermal limit
1	East Karbala-Abbas SS		0.6137
2	East Karbala-Abbas SS		0.6137
3	North Karbala-Shuhadaa SS		0.7828
4	North Karbala-Shuhadaa SS		0.7828
5	North Karbala-Al-Hur SS		0.2349
6	South Karbala-Al-Hur SS		0.2349
7	South Karbala-Al-Taawin SS		0.4619
8	South Karbala-Al-Taawin SS		0.4619
9	South Karbala-Al-Hussain SS		0.4072
10	South Karbala-Al-Hussain SS		0.4072
11	South Karbala-Al-Najaf SS		0.6047
12	South Karbala-Al-Najaf SS		0.6047
13	Al-Tahaddy mobile-Tahaddy SS		0.5691
14	Al-Tahaddy mobile-Tahaddy SS		0.5691
15	Al-Hindia mobile-Al-Hindia SS	47%	0.78
16	South Karbala-Kairat SS		0.7511
17	Al-Salam mobile-Al-Salam SS		0.736
18	South Karbala-Al-Salam SS		0.736
19	North Karbala-Aun SS		0.4113
20	North Karbala-Aun SS		0.4113
21	East Karbala-Al-Hussainia SS	38%	0.67

From the tables shown above; the loads that must be decreased from the received substation to minimize the line thermal limit are about 20 MVA from Al-Hindia substation and about 12 MVA from Al-Husainia substation. The percentage of loads are decreased until the thermal limit reach 0.78 (which represents the maximum value of thermal limit for the healthy lines in this network) also limited by the national standard of generation.

The above loads are selected to be the normal loads for the suggested microgrid s as Table (5) Microgrids Details

Table 5:

Microgrid No.	Location	Microgrid load (MVA)	Microgrid capacity (MVA)
Microgrid 1	Al-Hindia SS	20	30
Microgrid 2	Al-Husainia SS	12	20

The sources of the microgrids are designed to fed its normal loads during normal operation and fed the residual power to the main grid during abnormal operation of the main grid.

b. Power quality results:

The analysis result for Holy Karbala distribution network shows that it requires 650 MVA and the power delivered to the city from the main grid of Iraq is 400 MVA (with the emergency lines) and the duration of delivering electric power to the consumers 12 hour per day.

Table 6:

Power Quality Parameter	Without Microgrid	With Microgrid
SAIDA (hrs)	12	10.16
SAIFI	6	6
CAIDI (hrs)	2	1.69

The microgrids delivered about 50 MVA this additional power can improve the power quality from the consumer point of view as listed in table (6) below:

In the case of a distribution network without microgrids,each consumer has an average of 12 hours outage during a day with six times of interruption and each interruption last for two hours.

In the case of a distribution network with microgrids, each consumer has an average of 10.16 hours outage during a day with six times of interruption and each interruption last for 1.69 hours.

Conclusions:

Microgrid strategy has many advantages to the distribution networks and it is considered one of the most significant way to enhance the stability and power quality in the distribution networks.

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