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Voltage Collapse Detection in Iraqi Electrical Network Using Different Types of Indices

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Abstract: ***Voltage stability is anxious with the ability of a power system to protect worthy voltages at all buses in the framework under ordinary condition and in the wake of being liable to an unsettling influence. In this paper study and analyze the high voltage 400 kV in Iraqi electrical network. In order to identify the voltage collapse in Iraqi electrical network by using different types of indices, these indices provide reliable data about nearness of voltage instability in a PS. Two types of Indices used to analysis and detect the weakness bus voltage and weakness lines in the Iraqi electrical network, indices for detect weak buses such as: Power Transfer Stability Index (PTSI) and Voltage Collapse Predication Index (VCPI) and indices for detect weak lines such as: Fast Voltage Stability Index (FVSI), Line Stability Index (L_mn) and On Line Stability Index (LVSI). The effectiveness of these indexes is confirmed through 24 bus Iraqi networks under increased the load on each bus until reach to collapse point and then increased the load on QIM4 and AMR4 buses as well as consider the lines outage that was connected with these buses. From the simulation, the results clearly indicate and the performance of these indices is achieved and considered.***

Keywords: Voltage collapse, bus stability index, PTSI, VCPI, line stability index, (FVSI, L_{mn} and LVSI).

1. Introduction

In recent years, significant power system disappointments (framework power outage) have happened all the more oftentimes around the globe [1]. Some of these disappointments have been caused by voltage-instability issues. These circumstances lead, the VS issues, to a vital and dire sympathy toward electric utilities. Taking care of this issue is not the correct thing to be moved ahead on the grounds that a PS under the voltage instability occasion is normally scarce. It is troublesome or difficult to address this issue when it happened. Counteractive action of voltage-instability is probably direct one. Numerous scientists in PS voltage stability commit their attempts to distinguish the weakest bus of the system.

The weakest bus is considered as the bus that is prone to be the first bus of the system by confronting voltage collapse. Avoidance of voltage insecurity depends on placing the system weakest bus. Some effective activities can be utilized to put a working purpose of the system a long way from the voltage giving way point to a satisfactory edge. Static voltage dependability can be controlled by utilizing continuation force stream counts [2].

As power systems get to be more unpredictable and vigorously stacked, alongside temperate and natural requirements, voltage instability turns into an undeniably genuine issue, leading systems to work nearly as far as possible. Voltage instability is basically a neighbourhood marvel; be that as it may be its outcomes may have a broad effect. The investigation of voltage stability has been investigated under distinctive methodologies that can be fundamentally characterized into dynamic and static examination. The static voltage stability strategies depend mostly on the consistent state to demonstrate in the examination, for example, force stream model or a linearize element model depicted by the unfaltering state operation [3].

Voltage collapse is typically portrayed by an introductory moderate and dynamic diminishing in voltages and after that emulated by a quick decrease in voltage extent at different buses [1, 4]. It happens as a result of cooperation's among all quick and moderate elements in the power system network.

A conceivable grouping of occasions paving the way to voltage collapse can be described by burden build, drop in voltages at burden buses, generator programmed voltage controller (AVR) responding to brought terminal voltages so as down to create extra receptive force to support up the voltages, burden buses voltages keep on dropping, under burden tap changers endeavour to restore voltages after an introductory time delay, responsive stores at certain delicate generators approach their individual breaking points, region wide transport voltages decay steeply and afterward, the system collapse [5].

Subsequently, numerous variables need to concur and occasions need to happen all the while for a breakdown methodology to start. PS is regularly a vast element system in which the element conduct of its energy parts has a noteworthy impact on voltage breakdown. Right now, voltage instability is broadly acknowledged as being dynamic phenomena and in this manner it is important to consider element power framework models, for example, generator governors and exciters and instigation engine loads. To join the element parts of voltage insecurity investigation, time area reproduction procedure is typically utilized to create the time reaction of framework to a succession of discrete occasions. It is additionally ready to reveal insight into the component of voltage strength furthermore give remedial methodologies to enhance voltage security [6].

Finally, in this paper study and analyze the high voltage 400 kV in Iraqi grid system. In order to achieve the detection of the voltage collapse in Iraqi electrical network by using voltage stability Indices. These indices provide effective learning about proximity of voltage instability in a PS.

Usually, when the value is zero (voltage stable) and when the value is one (voltage collapse).

2. Voltage Stability Indices

Voltage stability indices can be assessed by utilizing a two machine coupling models. There exist numerous useful indices from literature. In this paper, Power Transfer Stability Index (PTSI), Voltage Collapse predication index (VCPI), Fast Voltage Stability Index (FVSI), Line Stability Index (L_mn) and On Line Stability Index (LVSI), are reviewed as follows.

2.1 Power Transfer Stability Index (PTSI)

The power transfer stability index (PTSI) is derived by considering a simple two buses Thevenin equivalent system, with a slack bus connected to a load bus by a single branch as showed in Figure (1).

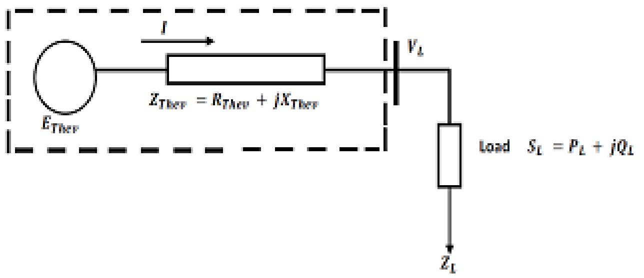

Figure 1: A Simple two bus Thevenin equivalent system.

$$PTSI = \frac{2S_L Z_{Thev}\left(1+\cos(\beta-\alpha)\right)}{E_{Thev}^2} \quad (1)$$

Where, S_L is the apparent power, Z_{Thev} is the Thevenin impedance, E_{Thev} is the Thevenin voltage, α is the phase angle of the load impedance and β is the phase angle of the Thevenin impedance.

Equation (1) shows PTSI is calculated at every bus by using information of the load power, voltage thevenin , impedance and load impedance phase angles. The value of PTSI index varies from 0 to 1 (voltage stability collapse). To maintain a secure condition, the value of PTSI index should be maintained less than 1[10].

2.2 Voltage Collapse predication index (VCPI)

To comparing and evaluating the effectiveness of using the PTSI, the Voltage Collapse Prediction Index (VCPI) is considered [7]. The value of VCPI index varies from 0 to 1 (voltage stability collapse). To maintain a secure condition, the value of VCPI index should be maintained less than 1. The VCPI for bus k is written as,

$$VCPI_k = 1 - \frac{\sum_{\substack{m=1\\ m\neq k}}^{N} V_m'}{V_k} \quad (2)$$

$$V_m' = \frac{Y_{km}}{\sum_{\substack{j=1\\ j\neq k}}^{N} Y_{kj}} V_m \quad (3)$$

Where, V_k is the voltage phasor at bus k, V_m is the voltage phasor at bus m, Y_{km} is the admittance between bus k and m, Y_{kj} is the admittance between bus k and j, *k* is the monitoring bus and *m* is the other bus connected to bus k [10].

2.3 Fast Voltage Stability Index (FVSI)

The line stability index FVSI proposed by [8] is based on a concept of power flow through a single line. For a typical transmission line shown in Figure (2), the stability index is calculated by:

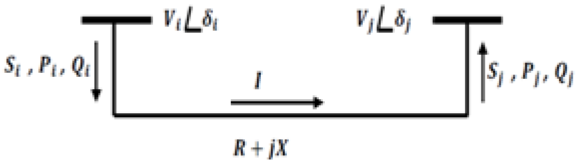

Figure 2: A Simple two bus power system.

$$FVSI_{ij} = \frac{4Z^2 Q_j X}{V_i^2 (R\sin\delta - X\cos\delta)^2} \quad (4)$$

Where *Z* is the line impedance, *X* is the line reactance, Q_j is the reactive power flow at the receiving end and V_i is the sending end voltage, *R* is the line resistance, δ is angle difference between sending and receiving buses. Lines that presents values of FVSI close to 1, indicates that those lines are closer to their instability points. To maintain a secure condition, the value of FVSI index should be maintained less than 1 [11].

2.4 Line Stability Index (L_{mn})

Derived a line stability index based on the power transmission concept in a single line, in which discriminate of the voltage quadratic equation is set to be greater or equal than zero to achieve stability. If the discriminate is small than zero, the roots will be imaginary, which means that cause instability in the system. Fig. (2) illustrates a single line of an interconnected network where the L_{mn} is derived from.

$$L_{mn} = \frac{4XQ_j}{[V_i \sin(\theta-\delta)]^2} \quad (5)$$

Where, *X* is the line reactance, Q_j is the reactive power flow at the receiving end and V_i is the sending end voltage, θ is the line impedance angle and δ is angle difference between sending and receiving buses. The value of L_{mn} that is evaluated close to 1 indicates that the particular line is close to its instability point which may lead to voltage collapse in the entire system. To maintain a secure condition, they L_{mn} should be maintained to be less than 1 [11].

2.5 On Line Stability Index (LVSI)

VSI is proposed from the relationship between line active power and the bus voltage with the line [9]. The active power and voltage quadratic equations must have real roots, as illustrated in a two-bus system in Figure (2).

$$LVSI_{ij} = \frac{4RP_j}{[V_i \cos(\theta-\delta)]^2} \quad (6)$$

Where, *R* is the line resistance, P_j is the active power flow at the receiving end and V_i is the sending end voltage, θ is the line impedance angle and δ is angle difference between sending and receiving buses. When the LVSI of one line approaches unity it means that the line is approaching its stability limits. The LVSI of all the lines must be lower than 1 to assure the stability of the power system [11].

3. Results and Discussion

Voltage stability indexes are performed on 24 Bus Iraqi electrical networks System. The simulation results are investigated in order to the study of only the 400 kV network with all its bus bars and transmission lines. The system configuration is shown in Figure (3). There are 11 generators, 19 loads and 39 transmission lines. The load consists of static and dynamic load (induction motor). Case studies are made for increased the load on each bus until reach to break down and then increased the load on QIM4 & AMR4 buses as well as consider the lines outage that was connected with this buses The aim of the simulations is to compare the performances of different indexes for identifying the proximity of voltage collapse.

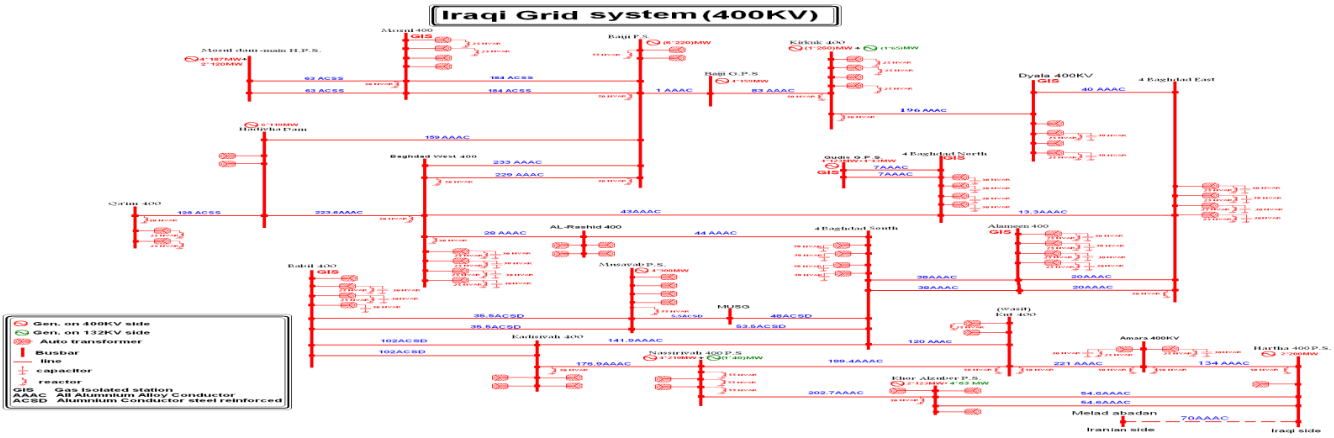

Figure 3: Configuration for 24 bus Iraqi electrical network system.

Figure (3) Configuration for 24 bus Iraqi electrical network system.

VSIs indicate the power transmission limit of this 24 bus Iraqi electrical network system. Under the influence of dynamic load, voltage instability may occur before or after power transmission limit. Although the failure of power restoration of dynamic load does not infer that voltage collapse occurs, the possibility of occurrence of voltage collapse will be increased a lot. Thus, it may be concluded that instability at dynamic load is one of the key phenomena of voltage collapse.

3.1 Case one: Load increase on each bus bar.

Load increasing on each bus until reach to breakdown as shown in Table (1).

Table (1) voltage stability indices due to load increasing

Bus Name	Maximum Load (MVA)	PTSI	VCPI
QIM4	373.469	0.9719	0.8035
AMR4	489.642	0.9723	0.8057
KDS4	574.406	0.9854	0.9003
DYL4	590.746	0.9894	0.9017
BAB4	609.919	0.9631	0.8067
AMN4	675.632	0.9764	0.9061

In Figures (4 &5) shows that the voltage with PTSI&VCPI indices for (QIM4) bus and (AMR4) bus respectively, and it's clear to prove that the PTSI indices are effective more than VCPI indices to detect the break down point.

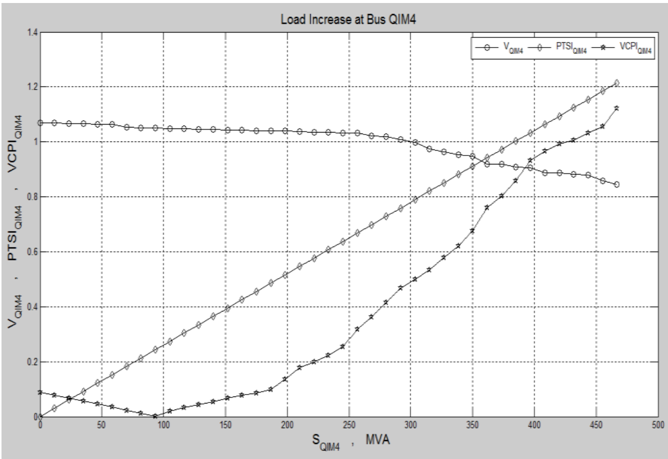

Figure 4: Load increasing at bus QIM4 (PTSI&VCPI).

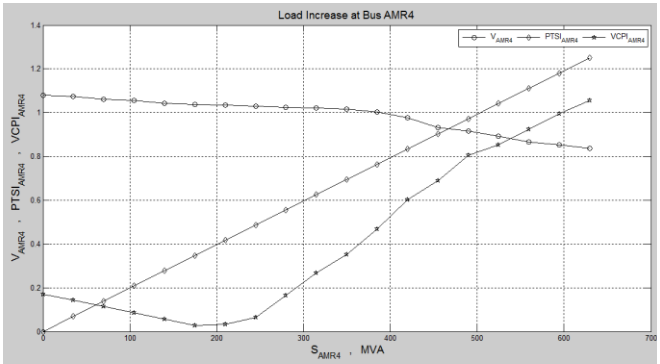

Figure 5: Load increasing at bus AMR4 (PTSI&VCPI)

Figure (6) shows which line is weak w r t to all network lines and connected between (HDTH-QIM4) line depended on the table (2) when exposed (QIM4) bus to maximum load or collapse.

Table 2: voltage stability indices due to load increasing at bus QIM4 and AMR4

Bus name with Max. Load	Line	FVSI	L_{mn}	LVSI
QIM4 = 373.469 MVA	BAJP-HDTH	0.9422	0.9422	---
	HDTH-BGW4	---	---	0.9341
	HDTH-QIM4	**0.9523**	**0.9523**	---
	BGW4-BGN4	---	---	0.9112
AMR4 = 489.642 MVA	MUSP-MUSG	0.8375	0.8375	---
	NSRP-KUT4	---	---	0.9214
	HRTP-AMR4	---	---	**0.9582**
	KUT4-AMR4	0.9271	0.9271	---

Figure (6) shows which line is weak w r t to all network lines and connected between (HDTH-QIM4) line depended on the table (2) when exposed (QIM4) bus to maximum load or collapse.

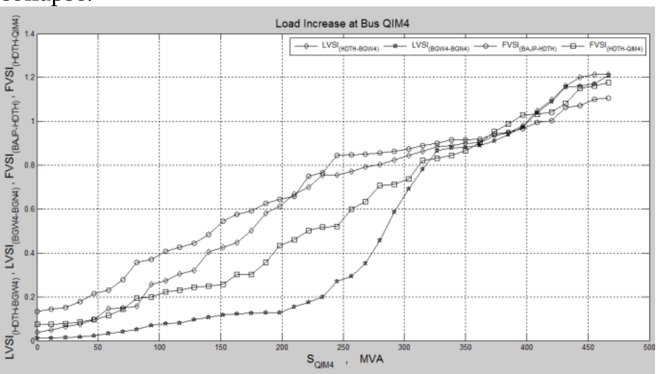

Figure 6: Load increasing at bus QIM4 (LVSI&FVSI).

Depending on Table (2) it's clear to notice that the AMR4 bus when exposed to collapse or maximum load the weakness line may be HRTP-AMR4 line as shown in Figure(7).

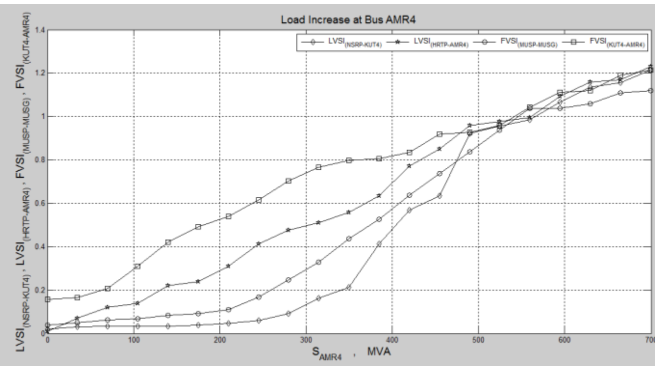

Figure 7: Load increasing at bus AMR4 (LVSI&FVSI).

3.2 Case two: Load increasing on (QIM4) bus and (AMR4) bus and disconnect the important lines that connected with it.

Until reach to collapse point as showed in Tables (3&4). Because the island area problem we didn't remove HDTH-QIM4.

Table 3: voltage stability indices due to lines outage (PTSI&VCPI)

Line Outage	BusName	Maximum Load (MVA)	PTSI	VCPI
BAJP-HDTH	QIM4	291.777	0.9975	0.8275
HRTP-AMR4	AMR4	279.795	0.9577	0.8228

Figures (8&9) shows that the weakness buses will be faster reached to collapse point comparing with load at first case.

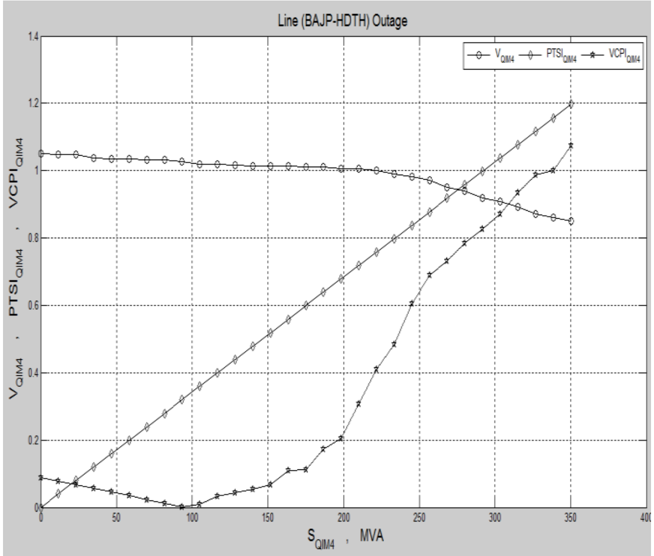

Figure 8: Line BAJP-HDTH outage (PTSI&VCPI).

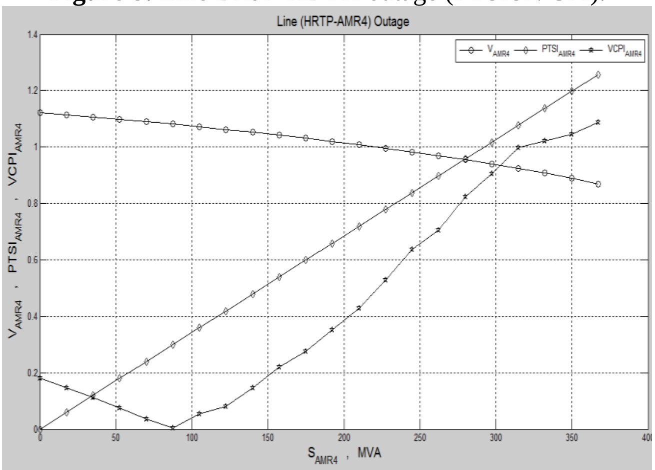

Figure 9: Line HRTH-AMR4 outage (PTSI&VCPI)

Table 4: voltage stability indices due to lines outage (LVSI, FVSI&L_{mn}).

Line Outage	Bus name with Max. Load	Line	FVSI	L_{mn}	LVSI
BAJP-HDTH	QIM4 = 291.777 MVA	HDTH-BGW4	---	---	0.9354
		HDTH-QIM4	**0.9625**	**0.9625**	---
		BGW4-BGN4	---	---	0.9127
HRTP-AMR4	AMR4 =279.795 MVA	MUSP-MUSG	0.8372	0.8372	---
		NSRP-KUT4	---	---	0.9264
		KUT4-AMR4	**0.9431**	**0.9431**	---

For weakness lines figures (10&11) shows that the collapse point may be faster than the increasing load at first case

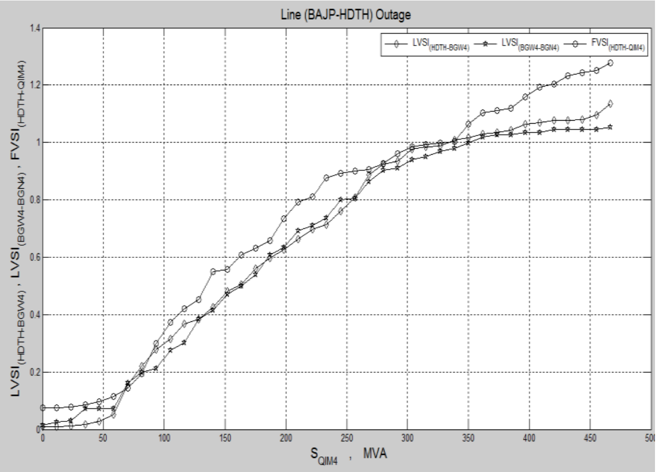

Figure10: Line BAJP-HDTH outage (LVSI&FVSI).

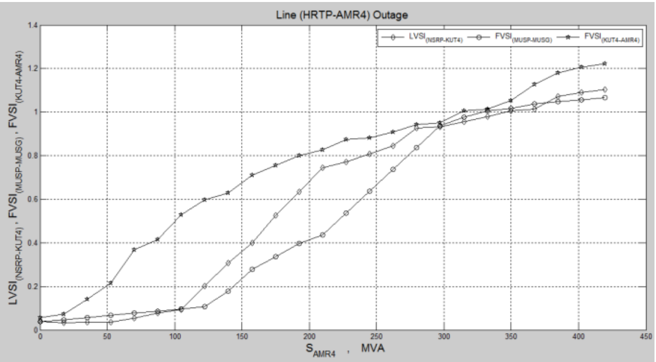

Figure 11: Line HRTP-AMR4 outage (LVSI&FVSI).

4. Conclusion

In this paper description and presents the performance of the five voltage stability indices. To comparing between two types of the indices of PTSI and VCPI used to monitor the buses voltage is presented with details. From simulation results, it can see that the PTSI is very effective than VCPI. Simulation results shows that the indicator on buses (QIM4 and AMR4) are considered the weakest bus in the 24 bus Iraqi system. And for lines monitors fast voltage stability index (FVSI) line stability index (Lmn) and On Line Stability Index (LVSI), are presented with details. Simulation results show that the indication on the lines (HDTH-QIM4 and HRTP-AMR4) are considered the weakest line in the 24 bus Iraqi system. From results FVSI is proportional directly with reactive power change on the lines and as comparing FVSI with Lmn it showed same effectiveness, and LVSI is proportional directly with active power change on the lines.

5. Acknowledgment

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Appendix

Symbol	Description
AMN4	Alameen 400 kV
AMR4	Alamara 400 kV
BAB4	Babil 400 kV
BAJG	Baiji Gas Power Station
BAJP	Baiji Power Station
BGC4	Baghdad Center 400 kV
BGE4	Baghdad East 400 kV
BGN4	Baghdad North 400 kV
BGS4	Baghdad South 400 kV
BGW4	Baghdad West 400 kV
DYL4	Diyala 400 kV
HDTH	Hadiytha Dam Hydro
HRTP	Hartha Power Station
KAZG	Khor Alzuber
KDS4	Kadisiyah 400 kV
KRK4	Kirkuk 400 kV
KUT4	Kut 400 kV

MMDH	Mosul Main Dam Hydro
MSL4	Mosul 400 kV
MUSG	Musayab Gas Power Station
MUSP	Musayab Power Station
NSRP	Nassiriyah Power Station
QDSG	Qudis Gas Power Station
QIM4	Qaim 400 kV

Author Profile

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