The International Journal of Engineering
And Science (IJES)
||Volume|| 1 ||Issue|| 2||Pages|| 124-142||2012||
ISSN: 2319 – 1813 ISBN: 2319 – 1805

A Comprehensive Distribution Methodology for Lighting Control and Automation Using KNX Bus System

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----------**Abstract**----------
The paper presents the KNX application model as the basis of the smart home automation concept implementation. The distribution details of lighting system in a villa using the KNX protocol are presented. Each luminary and switch is individually addressed allowing the entire system to be structured and to be modified via software. This effect gives the building virtual wiring that can be modified easily with little to no expense. Additionally the paper tries to evaluate the electrical energy saving lighting concept by using a relatively simple KNX system.

Keywords: Lighting, Villa, Distribution, KNX, Automation, Control, Cost.

Date Of Submission: 26 November, 2012 ⟺ Date Of Publication: 15, December 2012

1 Introduction

Home automation is the implementation of a system to automate, manage and control devices in a home via a single uniform system. It is helpful because it enables a buildings residents to be free from the day to day hassles of managing all the individual systems within a home separately. Via a single touch panel, all applications in a building can be controlled. From heating, ventilation and access control to the remote control of all household appliances – home automation (by the use of KNX Systems) allows completely new ways to increase comfort, safety and energy savings in the home.KNX Lighting Control allows to keep control of energy usage in buildings is a key contributing factor in protecting the environment. Controls using KNX can facilitate this control.

They can provide a comfortable working environment for building occupants enhancing productivity, ensure compliance with current energy legislation and contribute significantly to reduce energy usage leading to a smaller carbon footprint. Open communication between building systems facilitates strait forward and secure integration of third part systems at all levels, the standardization and independent communication that KNX provides ensures development and exchange of information between systems across the automation and field levels within the building automation topology.

The main aim in applying KNX in a building like villa is to develop the building and make it smarter to achieve the customer's satisfaction in feeling comfort. All equipment required for independent control and monitoring of building services plants as well as recording data. This covers the whole spectrum from individual room controllers up to integrated control systems. Also it can link the lighting control, solar protection and any special plants to the 'traditional' HVAC control. The versatility of the KNX protocol provides a flexible approach to room control and HVAC, whilst allowing easy integration to third party systems through a number of gateways available to automation platforms such as BACnet.

2 KNX Lighting Control Functions, [6], [1]

2.1. On/Off Switching

1. Operation as break contact/make contact.
2. Delay functions for each channel.
3. Staircase lighting functions with/without manual OFF function.
4. Scenes.

Fig.1 Switching Actuator

2.2. Dimming

Dimming actuator usage:

1- Dimming operation, different dimming curves and dimming speeds.
2- ON/OFF delay
3- Staircase time function with/without manual OFF function
4- Scenes.

Fig.2 Dimming Actuator

2.3. Blinding

Blind actuator usage: for raising curtain up or down

Fig.3 channels blind actuator

2.4. Presence sensor

Presence sensor Usage: for detecting the presence of any person enter the room to deliver a signal to the switching actuators to switch on loads, and the same scenario after leaving the room, it sends another signal to the switching actuator to switch off loads.

Fig.4 Presence Sensor

2.5. How to construct KNX protocol? [3], [6]

There are main steps to adjust KNX Protocol

2.5.1- Firstly

Connecting all loads which have the same controlling action.
Determine the most suitable actuator according to reliability and cost.
Referring each line to its channel of its actuator.
(EXP: Sw3/4: means this line will be connected to the switch actuator no. 3 at its forth channel).

2.5.2-Secondly:
After determining the most reliable actuators and -Arranging it in the distribution panel.
Connect each load to the channel of its actuator.
Determine the suitable power supply to connect it to the panel.
(By assuming that each actuator takes 10 MA (ref), and the rating of the power supplies ranges is (160 MA, 230 MA, 640 MA),

Hint: It is ok to connect to power supplies in the same panel for one cable but if the length of this cable not less than 200 M.

Only one cable is exit from the panel passing by all switches and sensors as In Fig5.
This connection might be in tree, line or star but never be loop.
(Because in case of loop when the switch or sensor send its signal to definite actuator to do the order, the signal will rotate in the loop and will not reach the actuator).
Inserting a description for the switches operation.

3. Applying KNX On The Ground Floor Of The Villa:

By Applying the steps:
Firstly: connecting all loads which have the same controlling action and referring each line to its channel of its actuator:

For Salon:
(L.S.3, L.S.4, L.S.5) are connected together to sw3/4.
(L.S.1) is connected alone to Dm.8/1.
(L.S.2) is connected alone to Dm.9/1.
(C.S.1) is connected alone to Bl.1/2.
(C.S.2) is connected alone to BL.1/1.

For Terrace:
(L.T.1, L.T.2, L.T.3) are connected to sw3/3.
For Dining room:
(L.D.1, L.D.2) are connected to Dm.16/1.
(L.D.3, L.D.4) are connected to Sw.2/1.

For Salon 1:
(L.S1.1) is connected to Dm.10/1.
(L.S1.2) is connected to Dm.11/1.
(L.S1.3) is connected to Dm.12/1.

For Stairs 2
(L.S.2) is connected Sw.3/2

For Entrance 5, Kitchen
(L.E.5, L.K., F.K) are connected to Sw.2/3

For Bathroom 1
(L.B.1, F.B.1) are connected to SW.2/2

For Hall, Stairs 3&4
(L.S.3, L.S.4) are connected Sw.3/1
(L.Hall) is connected to Dm.13/1.

For Entrances (3&4&5), Stairs
(L.E.3, L.E.4, L.E.5, L.S) are connected to sw.2/4

For Servant Bedroom
(L.Ser, L.ser2) are connected to Dm.15/1
(C.ser) is connected to Bl.2/1

For Bathroom 2
(L.B2.1, L.B2.2, F.B2) are connected to Sw.2/5

For Entrance 2
(L.E2.1, L.E2.2) are connected to Sw.2/6
For Entrance 1
(L.E1.1, L.E1.2) are connected to Sw.2/7.
For Living room
(L.LV.2, L.LV.3, L.LV.4) are connected to Sw.3/5
(L.LV.1) is connected to Dm.14/1

For Bathroom 3
(L.B3.1, L.B3.2, F.B3) are connected to Sw.2/8.

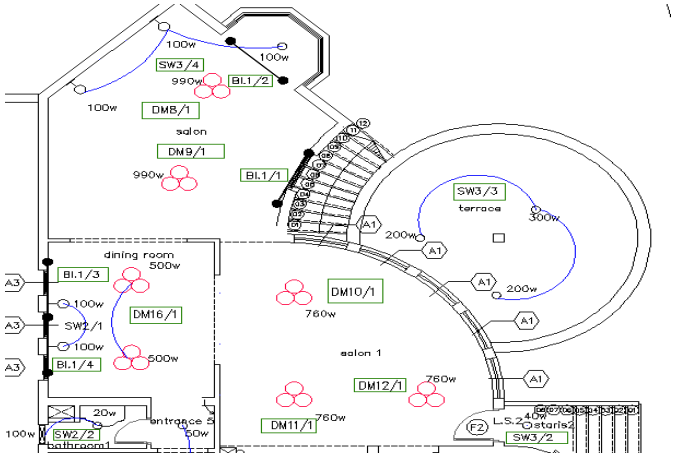

Fig.5 illustrates the connection of loads of common controlling action and the place of each line in its actuators. [4], [2], [3]

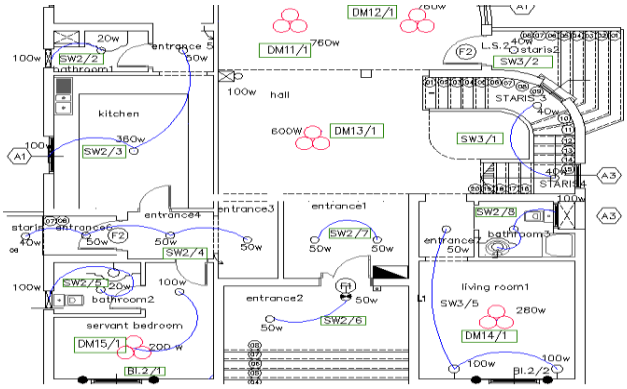

Fig.6 illustrates the connection of loads of common controlling action and the place of each line in its actuators [2-4].

-Tables that illustrate the symbols:

subject	Refer to
L.S.1	**First Lighting source in Salon.**
L.S.2	**Second Lighting source in Salon.**
L.S.3	**Third Lighting source in Salon.**
L.S.4	**Forth Lighting source in Salon.**
L.S.5	**Fifth Lighting source in Salon.**
C.S.1	**First Curtain in Salon.**
C.S.2	**Second Curtain in Salon.**
Bl.1/1	**Blind actuator (1)/Channel (1).**
Bl.1/2	**Blind actuator (1)/Channel (2).**
Sw.3/4	**Switching actuator (3)/Channel (4).**
Dm.8/1	**Dimming actuator (8)/Channel (1).**
Dm9/1	**Dimming actuator (9)/Channel (9).**

Table 1 illustrate the symbols used for salon

For Terrace

L.T.1	**First Lighting source in Terrace.**
L.T.2	**Second Lighting source in Terrace.**
L.T.3	**Third Lighting source in Terrace.**
Sw3/3	**Switching actuator (3)/Channel(3)**

Table 2 illustrate the symbols for terrace

For Dining room.

L.D.1	**First Lighting source in Dining room.**
L.D.2	**Second Lighting source in Dining room.**
L.D.3	**Third Lighting source in Dining room .**
L.D.4	**Forth Lighting source in Dining room.**
C.D.1	**First Curtain in Dining room.**
C.D.2	**Second Curtain in Dining room.**
Dm.17/1	**Dimming actuator (17)/Channel (1).**
Dm.18/1	**Dimming actuator (18)/Channel (9).**
Sw.2/1	**Switching actuator (2)/Channel(1)**
Bl.1/3	**Blind actuator (1)/Channel (3).**
BL.1/4	**Blind actuator (1)/Channel (4).**

Table 3 illustrate the symbols for dining room.

For Salon 1

L.S1.1	**First Lighting source in Salon1.**
L.S1.2	**Second Lighting source in Salon1.**
LS1.3	**Third Lighting source in Salon1.**
Dm.10/1	**Dimming actuator (10)/Channel (1).**
Dm.11/1	**Dimming actuator (11)/Channel (1).**
Dm.12/1	**Dimming actuator (12)/Channel (1).**

Table 4 illustrate the symbols used for salon 1

For Bathroom 1

LB1	**First Lighting source in Bathroom1.**
FB1	**Fan for bathroom 1.**
Sw2/2	**Switching actuator (2)/Channel(2)**

Table 5 illustrate the symbols for bathroom 1.

For Kitchen and entrance 5

L.K	**Lighting source in Kitchen.**
L.E.5	**Lighting source in Entrance 5.**
F.K	**Fan for kitchen.**
Sw2/3	**Switching actuator (2)/Channel(3)**

Table 5 illustrate the symbols used for salon

For Hall and stairs 2&3&4

L.Hall	**Lighting source in Hall.**
L.S.2	**Lighting source in Stairs 2.**
L.S.3	**Lighting source in stairs 3.**
L.S.4	**Lighting source in stairs 4.**
Dm 13/1	**Dimming actuator (13)/Channel (1).**
Sw.3/1	**Switching actuator (3)/Channel (1).**

Table 6 illustrate the symbols for Hall and stairs2&3&4

For Stairs, Entrance 6&4&3

L.S	**Lighting source in Stairs.**
L.E.6	**Lighting source in Entrance 6.**
L.E.4	**Lighting source in Entrance 4.**
L.E.3	**Lighting source in Entrance 3.**
Sw.2/4	**Switching actuator (2)/Channel (4).**

Table 7 illustrate the symbols For Stairs, Entrance 6&4&3
For Bathroom 2, and Servant room

F.B2	**Fan of Bathroom 2.**
L.B2.1	**First lighting source of Bathroom 2.**
L.B2.2	**Second lighting source of Bathroom 2.**
L.Ser	**First lighting source of Servant room.**
L.Ser.2	**Second lighting source of servant room.**
C.Ser	**Curtain of servant room.**
Dm.15/1	**Dimming actuator (15)/ Channel (1).**
SW.2/5	**Switching actuator (2) / Channel (5).**

Table 8 illustrate the symbols for bathroom2 and servant room.
For Entrance 1&2&7, Bathroom, 3, living room 1

L.E1.1	**First lighting source of Entrance 1.**
L.E1.2	**Second lighting source of Entrance1.**
L.E2.1	**First lighting source of Entrance 2.**
L.E2.2	**Second lighting source of Entrance2.**
L.LV.4	**Lighting source of Entrance 7.**
L.LV.1	**First lighting source of Living room.**
L.LV.2	**Second lighting source of Living room.**
L.LV.3	**Third lighting source of Entrance**
C.LV	**Curtain living room.**
L.B3.1	**First Lighting source Bathroom 3**
L.B3.2	**Second Lighting source Bathroom 3.**
F.B3	**Fan of Bathroom 3.**
Sw.2/8	**Switching actuator (2)/ Channel (8).**
SW.3/5	**Switching actuator (3)/ Channel (5).**
Dm.14/1	**Dimming actuator (14)/ Channel (1).**

Table 9 illustrate the symbols Entrance 1&2&7, Bathroom, 3, living room 1

Secondly:

The way of connecting switches and sensors in the rooms of the Ground Floor: Only one cable is exit from the panel passing by all switches and sensors as In Fig 5.

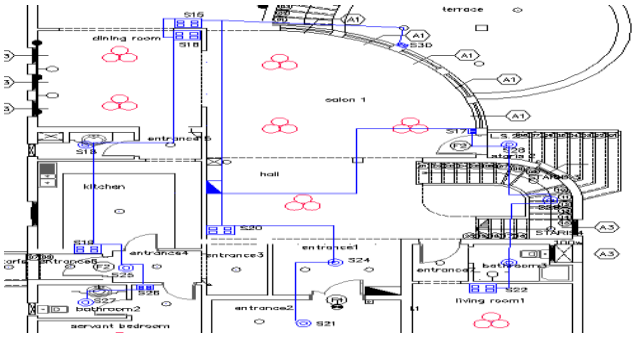

Fig.7 illustrates the way of connecting switches and sensors in the rooms of the Ground Floor: [4], [2], [3]

The Description of the switches operation in Ground Floor.

Switch 15:

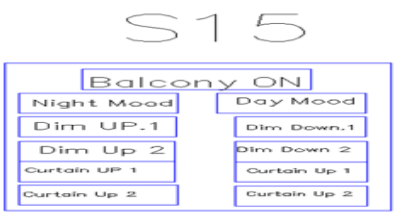

Fig 8 The Function of S15

A-Location: Salon
B-Loads controlled: L.S.1 & L.S.2 & L.S.3 & L.S.4 & L.S.5 & C.S.1 and C.S.2
C- When pressing (Night Mood): All Light sources went off except (L.s.1 &L.S.2) they dim to 80% of its power and all Curtains move down (off).
D-When pressing (Day Mood): All light sources go off and all curtains rise up
E-When Pressing (Dim down 1):L.S.1 dims down to 80% of its power.
F-When Pressing (Dim up 1): L.S.1 dim up till 100% of its power.
G-When pressing (Dim up 2) or (Dim down 2):L.S.2 is affected as L.S.1.
H-When pressing (Curtain up1) or (Curtain down 1): C.S.1 is affected to move up or down.
I-When pressing (curtain Up 2) or (curtain down 2): C.S.2 is affected to move up or down.

Switch 16:

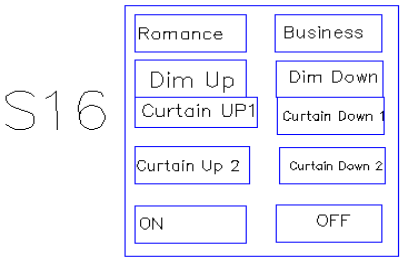

Fig 9 The function of S16

A-Location: Dining room
B-Loads controlled: L.D.1 & L.D.2 & L.D.3 & L.D.4 & C.D.1 and C.D.2
C-When pressing (Romance): L.D.1 & L.D.2 dim together to 80% of their power and C.D.1 & C.D.2 go down at the same time.
D-When pressing (Business): All light sources go on without dimming (100% of their power) and all curtains go down.
E-When Pressing (Dim down):L.D.1& L.D.2 dim down to 80% of its power.
F-when pressing (Dim up):L.D.1 & L.D.2 dim up till 100% of their power.
G-When pressing (Curtain up1) or (Curtain down 1): C.D.1 is affected to move up or down.
H-When pressing (curtain Up 2) or (curtain down 2): C.D.2 is affected to move up or down.
I- When pressing (ON) or (OFF): L.D.3 & L.D.4 turn on or off together.

Switch 17:

Fig 10 The Function of S3

A-Location: Salon1
B-Loads Controlled: L.S1.1 & L.S1.2 & L.S1.3
C- When pressing (Night Mood): (L.S1.1&L.S1.2& L.S1.3) will be dimmed together to 80% of their total power.
D-When pressing (Day Mood):): (L.S1.1& L.S1.2&L.S1.3) turn off together.
E- When Pressing (Dim down 1): (L.S1.1) dims down to 80% of its power.
When Pressing (Dim up 1): (L.S1.1) dims up till 100% of its power.
F- When Pressing (Dim down 2): (L.S1.2) dims down to 80% of its power.
G- When Pressing (Dim up 2): (L.S1.2) dims up till 100% of its power.
H-When Pressing (Dim down 3): (L.S1.3) dims down to 80% of its power.
I-When Pressing (Dim up 3): (L.S1.3) dims up till 100% of its power.

Switch 19:

Fig 11 The Function of S19

A-Location: Kitchen
B-Loads Controlled: L.E.5 & F.K & L.K
C- When pressing (Night Mood): (L.E.5&F.K&L.K) will turn on together.
D-When pressing (Day Mood): (L.E.5&F.K&L.K) turn off together.
E- When pressing (Light): (L.E.5 & L.K) will turn on.

Switch 20:

Fig 12 The Function of S20

A-Location: Hall
B-Loads controlled: L.Hall
E-When Pressing (Dim down):L.Hall dims down to 80% of its power.
F-when pressing (Dim up):L.Hall dims up till 100% of their power.

Switch 22:

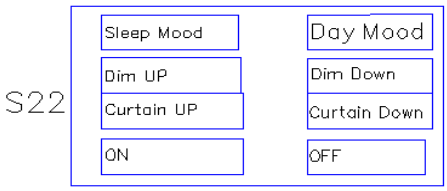

Fig 13 The Function of S22

A-Location: Living room
B-Loads controlled: L.LV.1 & L.LV.2 & L.LV3 & L.LV.4 & C.LV
C- When pressing (Sleep Mood): (L.LV.1 & L.LV.2 & L.LV3 & L.LV.4 & C.LV) turn to off together.
D-When pressing (Day Mood): (L.LV.1 & L.LV.2 & L.LV3 & L.LV.4) turn off together and C.LV turns to on.
E- When Pressing (Dim down): (L.LV.1) dims down to 80% of its power.
When Pressing (Dim up): (L.LV.1) dims up till 100% of its power.
F- When Pressing (Curtain up): (C.LV) moves up.
G- When Pressing (Curtain Down): (C.LV) moves down.
H-When Pressing (ON): (L.LV.2 & L.LV.3 & L.LV.4) turn on.
I-When Pressing (OFF): (L.LV.2 & L.LV.3 & L.LV.4) turn off

Switch 22:

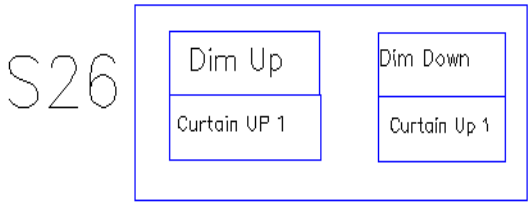

Fig. 14 The Function of s26

A-Location: Servant room
B-Loads Controlled: L.Ser & L.Ser.2 & C.Ser
C- When Pressing (Dim down): (L.Ser & L.Ser.2) dim down to 80% of its power.
D-when pressing (Dim up) :(L.Ser & L.Ser.2) dim up till 100% of their power.
E- When Pressing (Curtain up1): (C.ser) moves up.
F-When Pressing (Curtain Down1): (C.Ser) moves down.

Switch 29:

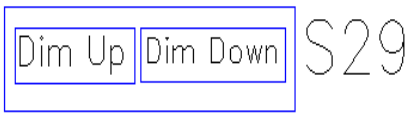

Fig 15 The function of S29

A-Location: Terrace
B-Loads controlled: L.T.1 & L.T.2 & L.T.3
E-When Pressing (Dim down): (L.T.1 & L.T.2 & L.T.3) dim down to 80% of its power.
F-when pressing (Dim up): (L.T.1 & L.T.2 & L.T.3) dim up till 100% of their power.

4. Applying KNX On The Upper Floor Of The Villa:

By Applying the steps:
Firstly: Connecting all loads which have the same controlling action and referring each line to its channel of its actuator:

For Master room:
(L.M.1, L.M.2) are connected together to Dm.1/1
(C.M.1) is connected to Bl.2/4
(C.M.2) is connected to Bl.2/3

For Terrace:
(L.T.1) is connected to Dm.2/1

For Dressing room:
(L.D.1, L.D.2, L.D.3, L.D.4) are connected together to Sw.1/2

For Bathrooms (1&2):
(L.B.1, L.B.2, Fan A) are connected together to Sw.1/3.
(L.B.3, L.B.4, Fan B) are connected together to Sw.3/4.
For corridors (1&2)
(L.Co.5oW (1), L.Co.5oW (2), L.Co.5oW (3), L.Co.5oW (4)) are connected together to Sw.1/4
(L.Co.60W (1), L.Co.60W (2), L.Co.6oW (3), L.Co.6oW (4), L.Co.6oW (5), L.Co.6oW (6)) are connected together to Sw.1/5
For Bedrooms (1&2&3), Entrance Hall
(L.BD.1 & L.E.1) are connected together to Dm.5/1
(C.BD.1) is connected to Bl.3/3
(L.BD.2) is connected to Dm.4/1
(C.BD.2) is connected to Bl.3/2
(L.BD.3) is connected to Dm.3/1
(C.BD.3) is connected to Bl.3/1

For Bathroom 3, Terrace 2, Stairs, Stairs2
(L.B.5, Fan C) are connected together to Sw.1/6
(L.T.2) is connected to Dm.6/1
(C.T.2) is connected to Bl.4/2
(L.S, LS2) are connected to Sw.1/8
For Living room
(L.LV.1, L.LV.2) are connected to Dm.7/1
(C.LV.1) is connected to Bl.4/1
(C.LV.2) is connected to Bl.3/4

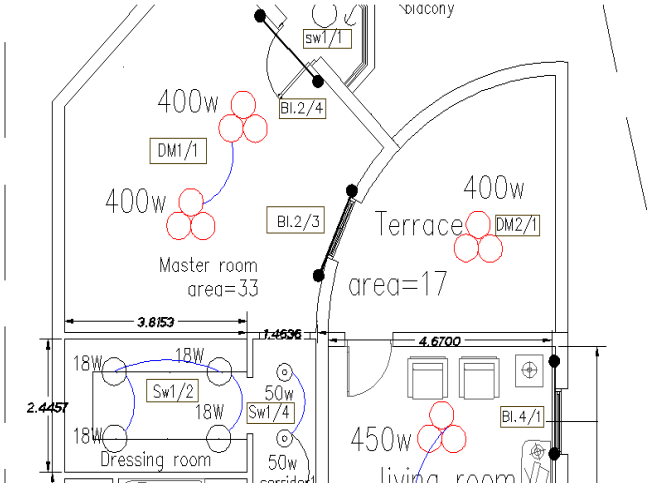

Fig.16 illustrates the connection of loads of common controlling action and the place of each line in its actuators. [4], [2], [3]

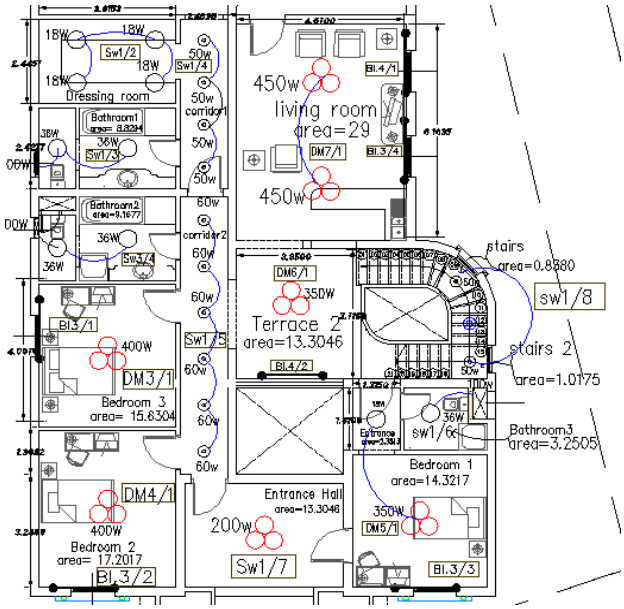

Fig.17 illustrates the connection of loads of common controlling action and the place of each line in its actuators. [4], [2], [3]

Tables to illustrate the symbols used.

For Master room and Balcony

subject	Refer to
L.M.1	First Lighting source in Master room.
L.M.2	Second Lighting source in Master room.
C.M.1	First Curtain in Master room.
C.M.2	Second Curtain in Master room.
Sw.1/1	Switching actuator (1)/Channel (1).
Dm.1/1	Dimming actuator (1)/Channel (1).
Bl.2/4	Blind actuator (2)/Channel (4).
Bl.2/3	Blind actuator (2)/Channel (3).
L.Blco	Lighting source in Balcony.

Table 10 illustrate the symbols for master room and balcony.

For Dressing room

L.D.1	First lighting source of Dressing room.
L.D.2	Second lighting source of Dressing room.
L.D.3	Third lighting source of Dressing room.
L.D.4	Forth lighting source of Dressing room.
Sw1/2	Switching actuator (1)/ Channel (2).

Table 11 illustrate the symbols for dressing room.

For Terrace

L.T.1	First Lighting source in Terrace.
Dm2/1	Dimming actuator (2)/Channel(1)

Table 12 illustrate the symbols for terrace.

For Living room

L.LV.1	First lighting source of Dressing room.
L.LV.2	Second lighting source of Dressing room.
C.LV.1	First Curtain in Living room.
C.LV.2	Second Curtain Living room.
Dm7/1	Dimming actuator (7)/ Channel (1).
BL.4/1	Blind actuator (4) / Channel (1).
Bl.3/4	Blind actuator (3) / Channel (4).

Table 13 illustrate the symbols for living room.

For Bathrooms (1 & 2 & 3)

L.B.1	First lighting source of Bathroom1.
L.B.2	Second lighting source of Bathroom 1.
L.B.3	First lighting source of Bathroom 2.
L.B.4	Second lighting source of Bathroom 2.
L.B.5	Lighting source of Bathroom 3.
Fan A	Fan of Bathroom 1.
Fan B	Fan of Bathroom 2.
Fan C	Fan of Bathroom 3.
Sw1/3	Switch actuator (1)/ Channel (3).
Sw1/6	Switch actuator (1)/ Channel (6).
Sw3/4	Switch actuator (3)/ Channel (4).

Table 14 illustrate the symbols for bathrooms 1&2&3.

For Bedrooms (1 & 2 & 3) and Entrance

L.BD.1	Lighting source of Bedroom1.
L.BD.2	Lighting source of Bedroom2.
L.BD.3	Lighting source of Bedroom3.
C.BD.1	Curtain of Bedroom 1.
C.BD.2	Curtain of Bedroom 2.
C.BD.3	Curtain of Bedroom 3.
Dm 3/1	Dimming actuator (3)/ Channel (1).
Dm 4/1	Dimming actuator (4)/ Channel (1).
Dm 5/1	Dimming actuator (5)/ Channel (1).
L.E.1	Lighting source of Entrance.
Bl.3/1	Blind actuator (3) / Channel (1).
Bl.3/2	Blind actuator (3) / Channel (2).
Bl.3/3	Blind actuator (3) / Channel (3).

Table 15 illustrate the symbols for bedrooms 1&2&3 and entrance.

For corridor 1

L.co.50W(1)	First Lighting source of Corridor1.
L.co.50W(2)	Second Lighting source of Corridor1.
L.co.50W(3)	Third Lighting source of Corridor1.
L.co.50W(4)	Forth Lighting source of Corridor1.
Sw1/4	Switch actuator (1)/ Channel (4).

Table 16 illustrate the symbols for corridor 1.
For Entrance Hall, Coridore2, Terrace 2, Stairs and Stairs2

L.E.H	Lighting source of Entrance Hall.
L.co.60W(1)	First Lighting source of Corridor 2.
L.co.60W(2)	Second Lighting source of Corridor 2.
L.co.60W(3)	Third Lighting source of Corridor 2.
L.co.60W(4)	Forth Lighting source of Corridor 2.
L.co.60W(5)	Fifth Lighting source of Corridor 2.
L.co.60W(6)	Sixth Lighting source of Corridor 2.
L.T.2	Lighting source of Terrace 2.
L.S	Light source of stairs 1.
L.S.2	Light source of stairs 2.
Sw1/5	Switch actuator (1)/ Channel (5).
SW1/7	Switch actuator (1)/ Channel (7).
SW 1/8	Switch actuator (1)/ Channel (8).
DM6/1	Dimming actuator (6)/ Channel (1).

Table 17 illustrate the symbols For Entrance Hall, Coridore2, Terrace 2, Stairs and Stairs2.

Secondly:
The way of connecting switches and sensors in the rooms of the Upper Floor: Only one cable is exit from the panel passing by all switches and sensors as In Fig 7

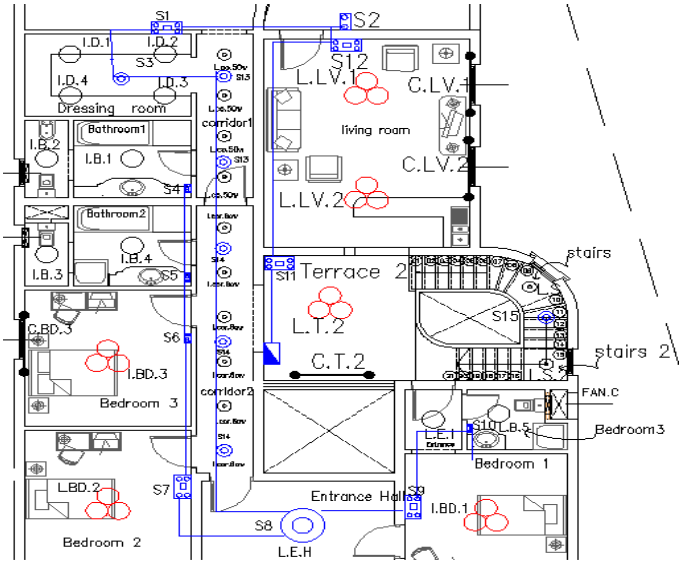

Fig.18 illustrates the way of connecting switches and sensors in the rooms of the Upper Floor: [2-4]

The Description of the switches operation in Ground Floor.
Switch 1

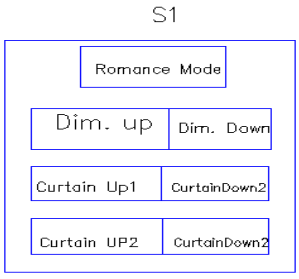

Fig 19 The function of S1

A-Location: Master room
B-Loads controlled: L.M.1 & L.M.2 & C.M.1 & C.M.2 & L. Blco
C-When pressing (Romance Mood): L.M.1 & L.M.2 dim together to 80% of their power; L. Balco turns to off and C.M.1 & C.M.2 go down at the same time.
D-When Pressing (Dim down):L.M.1& L.M.2 dim down together to 80% of their power.
F-when pressing (Dim up):L.M.1 & L.M.2 dim up together till 100% of their power.
G-When pressing (Curtain up1) or (Curtain down 1): C.M.1 is affected to move up or down.
H-When pressing (curtain Up 2) or (curtain down 2): C.M.2 is affected to move up or down.
Switch 2:

Fig 20 The Function of S2

A-Location: Terrace
B-Loads controlled: L.T.1
E-When Pressing (Dim down): (L.T.1) dims down to 80% of its power.
F-when pressing (Dim up): (L.T.1) dims up till 100% of their power.
Switch 6:

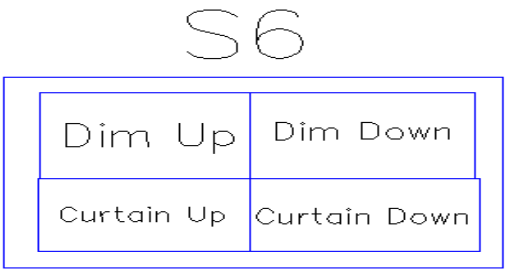

Fig 21 The Function of S6

A-Location: Bedroom 3
B-Loads Controlled: L.BD.3 & C.BD.3
C- When Pressing (Dim down): (L.DB.3) dims down to 80% of its power.
D-when pressing (Dim up) :(L.BD.3) dims up till 100% of their power.
E- When Pressing (Curtain up1): (C.BD.3) moves up.
F-When Pressing (Curtain Down1): (C.BD.3) moves down.

Switch 7:

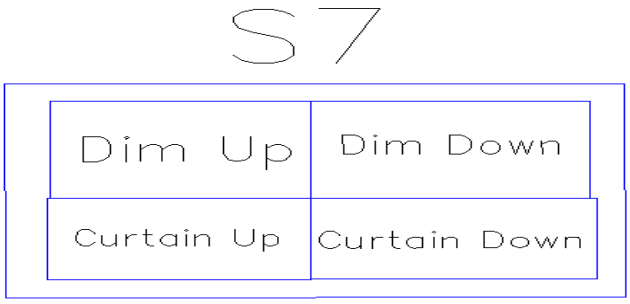

Fig 22 The Function of S7

A-Location: Bedroom 2
B-Loads Controlled: L.BD.2 & C.BD.2
C- When Pressing (Dim down): (L.DB.2) dims down to 80% of its power.
D-when pressing (Dim up) :(L.BD.2) dims up till 100% of their power.
E- When Pressing (Curtain up1): (C.BD.2) moves up.
F-When Pressing (Curtain Down1): (C.BD.2) moves down.
Switch 7:

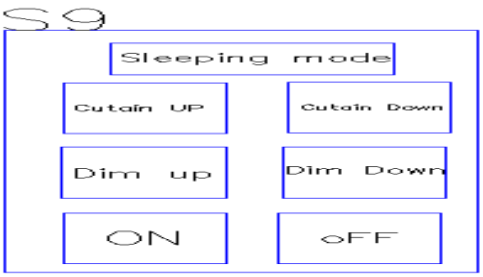

Fig 23 illustrate the function of S9

A-Location: Bedroom 1
B-Loads Controlled: L.BD.1 & C.BD.1 & L.E.1
C- When Pressing (Sleeping mode): (L.BD.1, C.BD.1, L.E.1) turn together off.
D-when pressing (Dim up) :(L.BD.1) dims up till 100% of their power.
E- When Pressing (Dim Down): (L.BD.1) dims down to 80% of its power.
F-When Pressing (Curtain Down): (C.BD.1) moves down.
H- When pressing (Curtain UP): (C.BD.1) moves up.
I-When pressing (ON): L.E.1 turns on.
J- When pressing (OFF): L.E.1 turns off.

Switch 11:

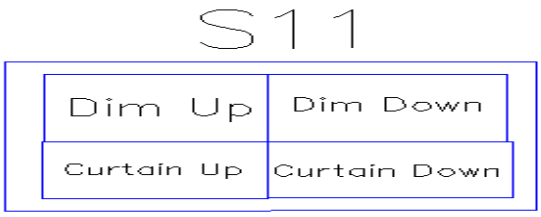

Fig 24 The function of S11

A-Location: Terrace 2
B-Loads Controlled: L.T.2 & C.T.2
C- When Pressing (Dim down): (L.T.2) dims down to 80% of its power.
D-when pressing (Dim up) :(L.T.2) dims up till 100% of their power.
E- When Pressing (Curtain up1): (C.T.2) moves up.
F-When Pressing (Curtain Down1): (C.T.2) moves down.

Switch 12:

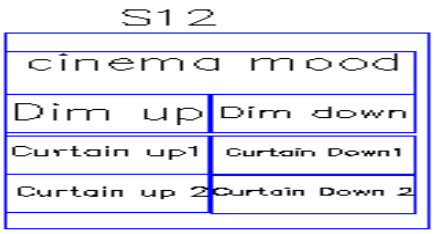

Fig 25 The Function of S12

A-Location: Living room
B-Loads controlled: L.LV.1 & L.LV.2 & C.LV.1 & C.LV.2
C-When pressing (Cinema mood): All loads turn off.
D-When Pressing (Dim down):L.LV.1& L.LV.2 dim down together to 80% of their power.
F-when pressing (Dim up):L.LV.1 & L.LV.2 dim up together till 100% of their power.
G-When pressing (Curtain up1) or (Curtain down 1): C.LV.1 is affected to move up or down.
H-When pressing (curtain Up 2) or (curtain down 2): C.LV.2 is affected to move up or down.

The presence sensor: when it detect movement of anybody under the area covered by its rays it send signal to its switch actuator to turn light/Fan on and after adjustable time of leaving this body it send another signal to the same switch actuator to turn light off.

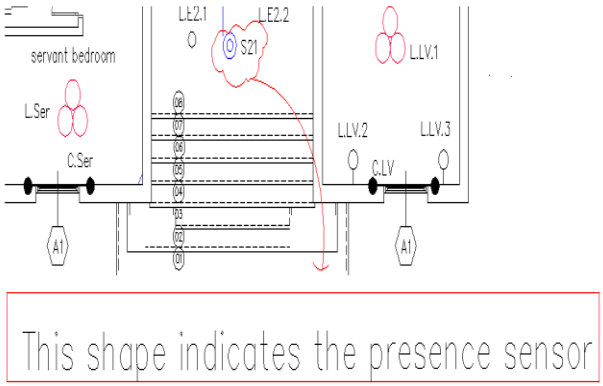

Fig. 26 The Presence Sensor

5. Calculating Total Cost For Design (With And Without KNX), [9]

Assume:-1 KWH =o.3 LE-The cost of each actuator used. (1)

No. of units used.	Description of Actuator. & its code.	No. of Channels /Rating Current or Watt for each unit.	Assumed Cost.
2	Switching actuator& Mtn646808	8/6A.	350 LE
1	Switching actuator&Mtn649204	4/10A.	400 LE
9	Dimming actuator & Mtn649310	1/1000w.	500 LE
5	Dimming actuator & Mtn649550	1/500W.	250 LE
1	Dimming actuator & Mtn646630	2/300w.	200 LE
4	Blind actuator & Mtn646704	4/6A.	350LE

Cost of each switch =500 LE.
Cost of Presence sensor =500 LE.
Total cost of this tools =2*350+1*400+9*500+5*250+1*200+4*350+ (30(Total no. of switches)* 500) = 23,450 LE.

Total cost of this tools =23,450 LE.

Assume that the lighting sources works for about 8 Hrs/Day.
Assume for dimming cases that the lighting source works for 2 Hrs without dimming and about 6 hrs with dimming 20%.
Assume for Switching cases that the load works for 5 hrs only.

In excel sheet, as shown is Fig.8
Calculation of cost per day without using KNX.
Power consumed in a day =Total Wattage/Hr *8 Hr
(Cost/ day=x LE) =Power Consumed in a day *10^ (-3)*0.3

Calculation of cost per day with using KNX.
Power consumed in a day (in case of dimming) = Total Wattage/Hr *2 Hr +Total Wattage/Hr *0.8*6 Hr.
Power consumed in a day (in case of switching) =Total Wattage *5hr.
(Cost/ day=x LE) =Power Consumed in a day *10^ (-3)*0.3

Table 18 : Calculation Total Power consumed cost in both Cases (With & Without KNX). Ground Floor

room	Total Watage /Hr	Power consumed in a day Without KNX	Cost/a day=x LE (without KNX)	Power consumed in a day with KNX	Cost / day=x LE (with KNX)	Type of operation
salon (Dimming)	2280	18240	5.472	15504	4.6512	Dimming
Salon (Switching)	300	2400	0.72	1500	0.45	Switching
kichen	460	3680	1.104	2300	0.69	Switching
servant bedroom	300	2400	0.72	2040	0.612	Dimming
bathroom 2	140	1120	0.336	700	0.21	Switching
Dining room(Dimming)	1000	8000	2.4	6800	2.04	Dimming
Dining room (switching)	200	1600	0.48	1000	0.3	Switching
bathroom 1	120	960	0.288	600	0.18	Switching
entrance 5	50	400	0.12	250	0.075	Switching
entrance 4	50	400	0.12	250	0.075	Switching
entrance 3	50	400	0.12	250	0.075	Switching
entrance 2	100	800	0.24	500	0.15	Switching
entrance 1	100	800	0.24	500	0.15	Switching
entrance 6	50	400	0.12	250	0.075	Switching
salon 1	2280	18240	5.472	15504	4.6512	Dimming
hall	700	5600	1.68	4760	1.428	Dimming
bathroom 3	140	1120	0.336	700	0.21	Switching
living room 1(Dimming)	280	2240	0.672	1904	0.5712	Dimming
living room 1(Switching)	200	1600	0.48	1000	0.3	Switching
stairs1	40	320	0.096	200	0.06	Switching
staris 2	40	320	0.096	200	0.06	Switching
stairs 3	40	320	0.096	200	0.06	Switching
Staris 4	40	320	0.096	200	0.06	Switching
terrace	700	5600	1.68	3500	1.05	Switching
entrance 7	50	400	0.12	250	0.075	Switching

Table 19 illustrate the cost with and without KNX

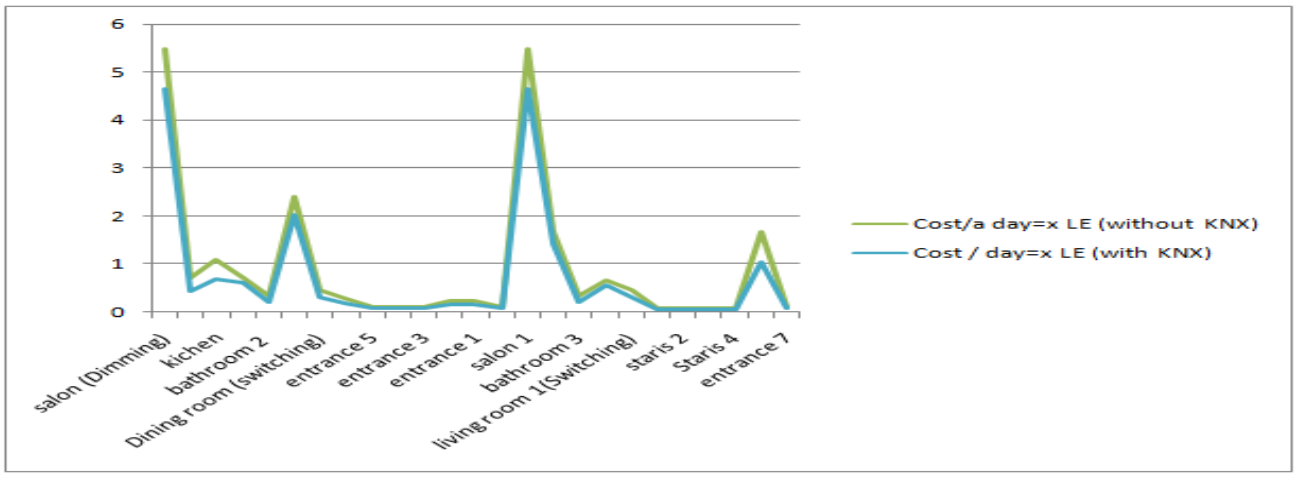

Fig.27 Graph illustrates relation between costs in both cases

Upper Floor

Room	Total Watage /Hr	Power consumed in a day W	Cost/a day=x LE (without KN	Power consumed in a day wi	Cost / day=x LE (with KNX)	type of operation
bedroom1	350	2800	0.84	2380	0.714	Demming
bedroom2	400	3200	0.96	2000	0.6	Demming
terrace	350	2800	0.84	2380	0.714	Demming
bedroom3	400	3200	0.96	2000	0.6	Demming
living room	900	7200	2.16	6120	1.836	Demming
entrance hall	200	1600	0.48	1000	0.3	Switching
terrace	400	3200	0.96	2000	0.6	Demming
master bedroom	800	6400	1.92	4000	1.2	Demming
balacony	25	200	0.06	125	0.0375	Switching
bathroom1	172	1376	0.4128	860	0.258	Switching
bathroom 2	172	1376	0.4128	860	0.258	Switching
bathroom 3	136	1088	0.3264	680	0.204	Switching
Entrance	18	144	0.0432	122.4	0.03672	Switching
Dressing room	72	576	0.1728	489.6	0.14688	Switching
corridor1	200	1600	0.48	1000	0.3	Switching
corridor2	360	2880	0.864	2448	0.7344	Switching
stairs	50	400	0.12	250	0.075	Switching
stairs 2	50	400	0.12	250	0.075	Switching

Table 20 The cost with and without KNX

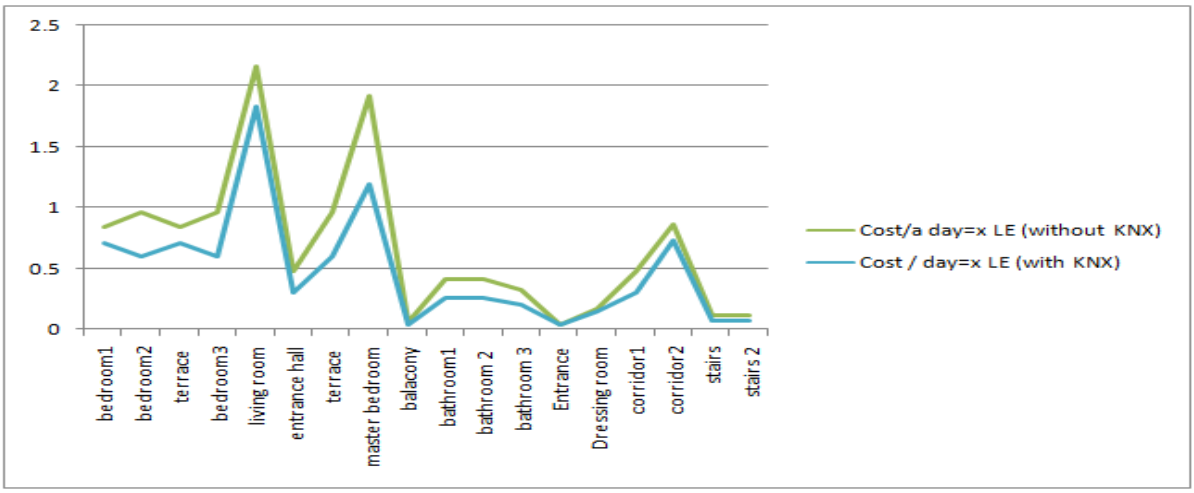

Fig.28 The Relation Between Costs in Both Cases

The excel sheets in Tables 19 and 20 illustrate the reduction in energy consumptions in both ground and first floors. The relations between the costs are illustrated in Figs. 27 and 28. Different results that estimate the energy savings show that the saving in lighting energy may reach 15 %.

6.Conclusion

The use of KNX model simplifies the integration of existing technologies. It can also ease market adoption, by abstracting home automation hardware and focusing on end user services. The KNX system is highly configurable, with the inclusion of a presence daylight sensor you can enter a room not only will the lights will come on but the sensor detects the lux level in the room and compensates the artificial light so a balance is formed to give the optimum lighting level for functionality and comfort. Applying KNX Protocol in this villa lowers the total cost, but actually this save in energy and for sure in money in small building like villa or either a house isn't as effective as in large buildings like mall for example.

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